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Consolidated Water Supply Plan SUPPORT DOCUMENT

Water Supply Department
South Florida Water Management District

Updates included in this version (2.1)

Chapter 2

- Updated description of St. Lucie and Loxahatchee Rivers in the Major Lakes and Rivers section.
- Updated Indian River Lagoon – South Project section.
- Updated Southwest Florida Feasibility Study section.
- Restructured Regional Restoration Projects section.

Chapter 3

- Updated surface water storage costs table.
- Restructured Water Source Options section.

Chapter 5

- Simplified Table 3.

Chapter 6

- Restructured Water Needs section.

Chapter 7

- Updated Indian River Lagoon – South Project information.
- Resturctured Water Needs section.

Chapter 8

- Restructured Water Needs section.

Chapter 9

- Updated WSE Schedule information.
- Restructured Water Resourcs and System Overview section.
- Resturctured Water Needs section.

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Acronyms and Abbreviations

ASR	aquifer storage and recovery
AWWA	American Water Works Association
BCBB	Big Cypress Basin Board
bls	below land surface
BGY	billion gallons per year
BMPs	Best Management Practices
BOD	biological or biochemical oxygen demand
BOR	Basis of Review
C&SF	Central and Southern Florida
C&SF Project	Central and Southern Florida Flood Control Project
CARL	Conservation and Recreational Lands
CCMP	Comprehensive Conservation and Management Plan
CERP	Comprehensive Everglades Restoration Plan
cfs	cubic feet per second
CHNEP	Charlotte Harbor National Estuary Program
CIWQ	Comprehensive Integrated Water Quality
COD	Chemical Oxygen Demand
CREW	Corkscrew Regional Ecosystem Watershed
CUP	Consumptive Use Permitting
CWMP	Caloosahatchee Water Management Plan
DBP	Disinfection By-Product
D/DBPR	Disinfectant/Disinfection By-Product Rule
DIP	ductile iron pipe
District	South Florida Water Management District
DRI	Development of Regional Impacts
DWMP	District Water Management Plan
DWSA	Districtwide Water Supply Assessment
EAA	Everglades Agriculture Area
ED	Electrodialysis
EDD	Everglades Drainage District
EDR	Electrodialysis Reversal
EEL	Environmentally Endangered Lands

ET	evapotranspiration
F.A.C.	Florida Administrative Code
FAS	Floridan Aquifer System
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FLUCCS	Florida Land Use and Cover Classification System
FPFWCD	Fort Pierce Farms Water Control District
FPL	Florida Power and Light
F.S.	Florida Statutes
FWC	Florida Fish and Wildlife Conservation Commission
GAC	Granular Activated Carbon
GIS	geographic information system
GPD	gallons per day
GPD/ft	gallons per day per unit foot
GPM	gallons per minute
GWUDI	Groundwater Under the Direct Influence of Surface Water
IAS	Intermediate Aquifer System
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFAS	Institute of Food and Agricultural Sciences
IR	indicator region
IRL	Indian River Lagoon
IRLFS	Indian River Lagoon Feasibility Study
IRLN	Indian River Lagoon – North Feasibility Study
IRL NEP	Indian River Lagoon National Estuary Program
IRLS	Indian River Lagoon – South Feasibility Study
KB	Kissimmee Basin
KB Plan	Kissimmee Basin Regional Water Supply Plan
LEC	Lower East Coast
LEC Plan	Lower East Coast Regional Water Supply Plan
LFA	lower Floridan Aquifer
LOPA	Lake Okeechobee Protection Act
LWC	Lower West Coast
LWC Plan	Lower West Coast Regional Water Supply Plan
MCL	Maximum Contaminant Level

MFL	minimum flow and level
MGD	million gallons per day
mg/L	milligrams per liter
MGY	million gallons per year
MIL	mobile irrigation laboratory
MWC	molecular weight cutoff
NEP	National Estuary Program
NGVD	National Geodetic Vertical Datum
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSLRWCD	North St. Lucie River Water Control District
NWI	National Wetlands Inventory
P2000	Preservation 2000
PLRG	pollutant load reduction goals
PMP	Project Management Plan
ppm	parts per million
psi	pounds per square inch
PSLSWU	Port St. Lucie Storm Water Utility
PWS	public water supply
Restudy	Central and Southern Florida Project Comprehensive Review Study
RO	reverse osmosis
RWSP	Regional Water Supply Plan
SAS	Surficial Aquifer System
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SLE	St. Lucie Estuary
SLR	St. Lucie River
SOR	Save Our Rivers
SPF	Standard Project Flood
STA	stormwater treatment area
SWFFS	Southwest Florida Feasibility Study
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement and Management

TDS	total dissolved solids
THM	Trihalomethane
TTHM	Total Trihalomethanes
TMDL	total maximum daily loads
TOC	total organic carbon
UEC	Upper East Coast
UEC Plan	Upper East Coast Regional Water Supply Plan
UFA	upper Floridan Aquifer
ULFA	upper part of the lower Floridan Aquifer
ULV	ultralow volume
USACE	United States Army Corps of Engineers
USDW	Underground Source of Drinking Water
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCAs	Water Conservation Areas
WOD	Works of the District
WPA	Water Preserve Area
WRDA	Water Resources Development Act
WSE	Water Supply and Environmental
WSTB	Water Science and Technology Board
WTP	Wastewater Treatment Plan

CHAPTER 1
Introduction

The South Florida Water Management District (SFWMD or District) has undertaken development of long-term comprehensive regional water supply plans to provide better management of south Florida's water resources. Chapter 373, Florida Statutes (F.S.), requires the District to prepare water supply plans for regions that have the potential for demands to exceed available supplies over a 20-year future time horizon. The District has committed to preparing water supply plans for each of its four planning regions (**Figure 1**), which cumulatively cover the entire District. Hydrologic divides generally define these regions.

The purpose of the water supply plans is to develop strategies to meet the future water demands of urban and agricultural uses, while meeting the needs of the environment. This process identifies areas where historically used sources of water will not be adequate to meet future demands, and evaluates several water source options to meet the deficit.

This Support Document includes information, assumptions and potential water source options to address statutory requirements through the year 2025. The information compiles characteristics of the SFWMD and its planning regions on topics related to the SFWMD's water supply planning and implementation activities.

BASIS OF WATER SUPPLY PLANNING

Legal Authority and Requirements

In 1972, the Florida Legislature created the water management districts to manage the state's water resources for various purposes, including water supply. The 1997 Florida Legislature adopted more specific legislation concerning the role of the water management districts in water resource and water supply planning and development. The legislative intent was to provide for current and future human and environmental demands for a 20-year planning horizon.

Water supply planning activities were first required of the state's water management districts following adoption of the *Florida Water Resources Development Act of 1972* (Chapter 373, F.S.). The authors of "*A Model Water Code*" (Maloney *et al*., 1972), upon which much of Chapter 373 is based, theorized that proper water resource allocation could best be accomplished within a statewide, coordinated planning framework. The State Water Use Plan and the State Water Policy were the primary documents formulated to meet this objective.

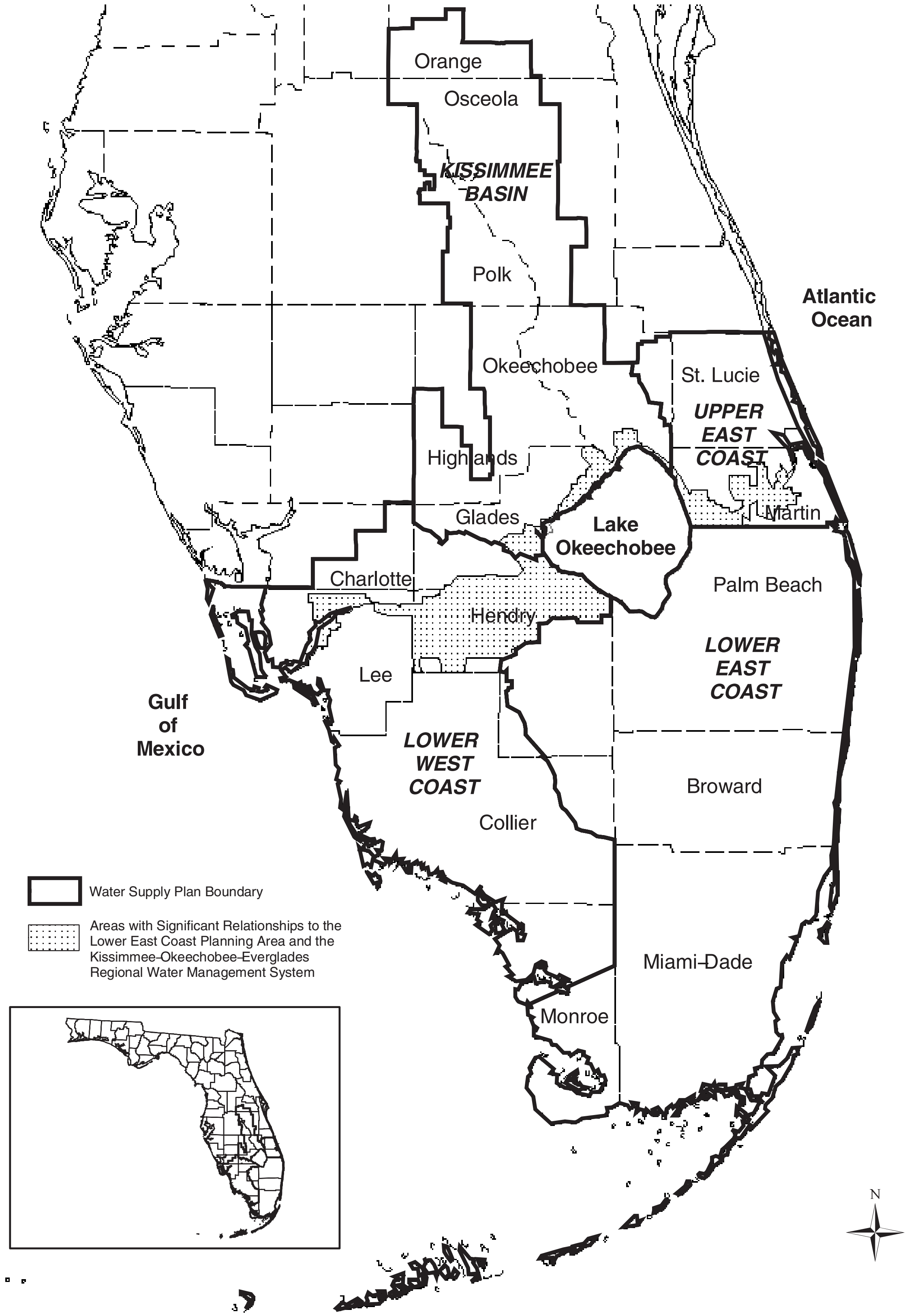

Figure 1. Planning Areas of the South Florida Water Management District.

With the passage of subsequent legislative amendments, the Legislature eliminated the State Water Use Plan and called for the development of the Florida Water Plan. The Florida Water Plan is required to include the Water Resource Implementation Rule (formerly known as the State Water Policy) and District Water Management Plans (DWMPs).

The Water Resource Implementation Rule [(Chapter 62-40 Florida Administrative Code (F.A.C.)] sets forth goals, objectives and guidance for the development and review of water resource programs, rules and plans. These directives are prescribed in the *Water Resources Act* (Chapter 373, F.S.), the *Florida Air and Water Pollution Control Act* (Chapter 403, F.S.) and the *State Comprehensive Plan* (Chapter 187, F.S.). These statutes provide the basic authorities, directives and policies for statewide water management, pollution control and environmental protection. The current legal framework for water supply planning is shown in **Figure 2**.

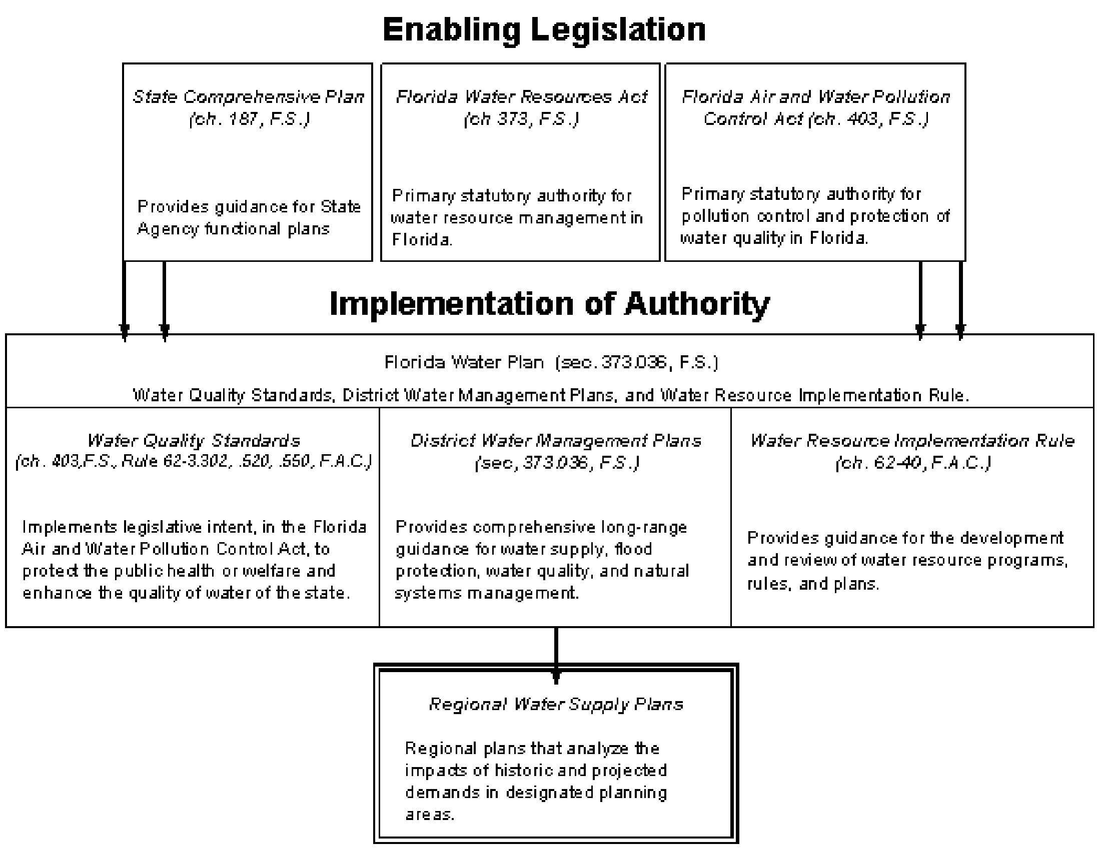

Figure 2. Legal Framework for Water Supply Planning.

The overall goal in water supply plans is derived from the State Comprehensive Plan:

> Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present level of surface and groundwater quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards.

WATER SUPPLY PLANNING INITIATIVE

Water Supply Planning History

The current SFWMD initiative in water supply planning began with the development of a Water Supply Policy Document (1991). At the time, Section 373.036, F.S., required water management districts to prepare assessments of water needs and supply sources. The District, through discussions with the Florida Department of Environmental Protection (FDEP), bifurcated this process, and prepared a Districtwide needs and sources analysis to be followed by regional water supply plans. The Water Supply Needs and Sources Document (July 1992) provided a preliminary analysis of the District's water demand and available resources, provided information to local governments (pursuant to Section 373.0391 and Section 373.0395, F.S.) and facilitated the completion of the *District Water Management Plan* (DWMP). The District approved DWMPs in 1995, 2000 and an update in 2002, which provide a comprehensive examination of the complex issues of water supply, flood protection, water quality and natural systems management in south Florida.

Statutory mandates for planning and development by the water management districts, in cooperation with the FDEP, are found in several sections of Chapter 373, F.S. Subsection 373.036(1), F.S. requires the FDEP to develop the Florida Water Plan in cooperation with the water management districts, regional water supply authorities and others. The Florida Water Plan includes, but is not limited to, the following items:

- The programs and activities of the FDEP related to water supply, water quality, flood protection and floodplain management and natural systems.
- The water quality standards of the FDEP.
- The district water management plans.
- Goals, objectives and guidance for the development and review of programs, rules and plans relating to water resources, based on statutory policies and directives [the State Water Policy, renamed the Water Resource Implementation Rule pursuant to Subsection 373.019(20), F.S., shall serve as this part of the Plan (Chapter 62-40, F.A.C.)].

- Regional water supply planning and development is mandated under:

Section 373.0361(1), F.S. By October 1, 1998, the governing board shall initiate water supply planning for each water supply planning region identified in the district water management plan under s. 373.036, where it determines that sources of water are not adequate for the planning period to supply water for all existing and projected reasonable-beneficial uses and to sustain the water resources and related natural systems. The planning must be conducted in an open public process, in coordination and cooperation with local governments, regional water supply authorities, government-owned and privately owned water utilities, self-suppliers, and other affected and interested parties. A determination by the governing board that initiation of a regional water supply plan for a specific planning region is not needed pursuant to this section shall be subject to s. 120.569. The governing board shall reevaluate such a determination at least once every 5 years and shall initiate a regional water supply plan, if needed, pursuant to this subsection.

Districtwide Water Supply Assessment

In 1997 Chapter 373, F.S. was modified, changing several water supply planning requirements. Among these was the introduction of a requirement for each water management district to prepare a Districtwide Water Supply Assessment (DWSA). Part of the analysis completed in the DWSA was to identify areas that had the potential for demands exceeding available supplies (without causing unacceptable environmental impacts) over a 20-year future time horizon, and for these areas, each District was required to prepare regional water supply plans. The Districtwide Water Supply Assessment (SFWMD, July 1998) confirmed the decision for the SFWMD to prepare water supply plans that cumulatively cover the entire SFWMD.

Regional Water Supply Plans

Regional water supply plans (RWSPs) provide more detailed, region-specific information than the water supply assessments. Within each RWSP, analyses are conducted that evaluate the impacts of projected demands on available water resources and water resource related natural systems. If projected impacts are more severe than a predefined threshold, then recommendations are made to increase the availability of additional water resources until the impacts are reduced below the threshold.

Each regional water supply plan is based on at least a 20-year planning and development period and includes, but is not limited to the following components:

- A water supply development component.
- A water resource development component.
- A recovery and prevention strategy for addressing attainment and maintenance of minimum flows and levels (MFLs) in priority water bodies.
- A funding strategy for water resource development projects that shall be reasonable and sufficient to pay the cost of constructing or implementing all of the listed projects.
- Consideration of how the options addressed serve the public interest or save costs overall by preventing the loss of natural resources or avoiding greater future public expenditures for water resource development or water supply development (unless adopted by rule, these considerations do not constitute final agency action).
- The technical data and information applicable to the planning area that are contained in the DWMP (SFWMD, 2000f) and necessary to support the RWSPs.
- The MFLs established for water resources within the planning area.

CHAPTER 2
Natural Systems

OVERVIEW

The location of south Florida between temperate and subtropical latitudes, the proximity to the West Indies, the expansive wetland system of the greater Everglades and the low levels of nutrient inputs under which the Everglades evolved, all combine to create a unique and species-rich flora and vegetation mosaic. Today the majority of south Florida's native vegetation has been substantially altered by drainage and development, resulting in hydrology changes, nutrient inputs and the spread of exotics, resulting directly or indirectly from a century of water management (USACE, 1999).

Much of Florida's shoreline and adjacent coastal ridges have been developed for urban use. The hammock and dune communities along the beaches are unique subtropical ecosystems that have very little protection and are rapidly disappearing. The remaining natural areas are threatened by continuing development and rising sea levels. Problems are especially apparent in areas where fresh water historically flowed from rivers, streams and wetlands into estuarine systems. Reduced freshwater flows have caused saltwater intrusion of some river systems, while coastal lagoons have experienced prolonged hypersaline conditions affecting water quality and estuarine biota.

South Florida's largest natural feature is the Kissimmee – Lake Okeechobee – Everglades (KOE) ecosystem (**Figure 3**). The KOE watershed consists of the Kissimmee Chain of Lakes, Kissimmee River, Lake Okeechobee and the Everglades covering an area of about 9,000 square miles. This watershed once extended as a single hydrologic unit from present-day Orlando 250 miles to the south to Florida Bay. Water from lakes and wetlands in the Kissimmee River Chain of Lakes region overflowed natural drainage divides during wet periods and moved slowly southward through the Kissimmee River, 90 miles to Lake Okeechobee. When water levels within Lake Okeechobee were high enough, water flowed south over the south rim of the lake into the extensive wetlands of the Everglades. These waters in turn, moved slowly 100 miles south across vast sawgrass plains, aquatic sloughs and tree islands to the coastal estuaries of Florida Bay and the Ten Thousand Islands area.

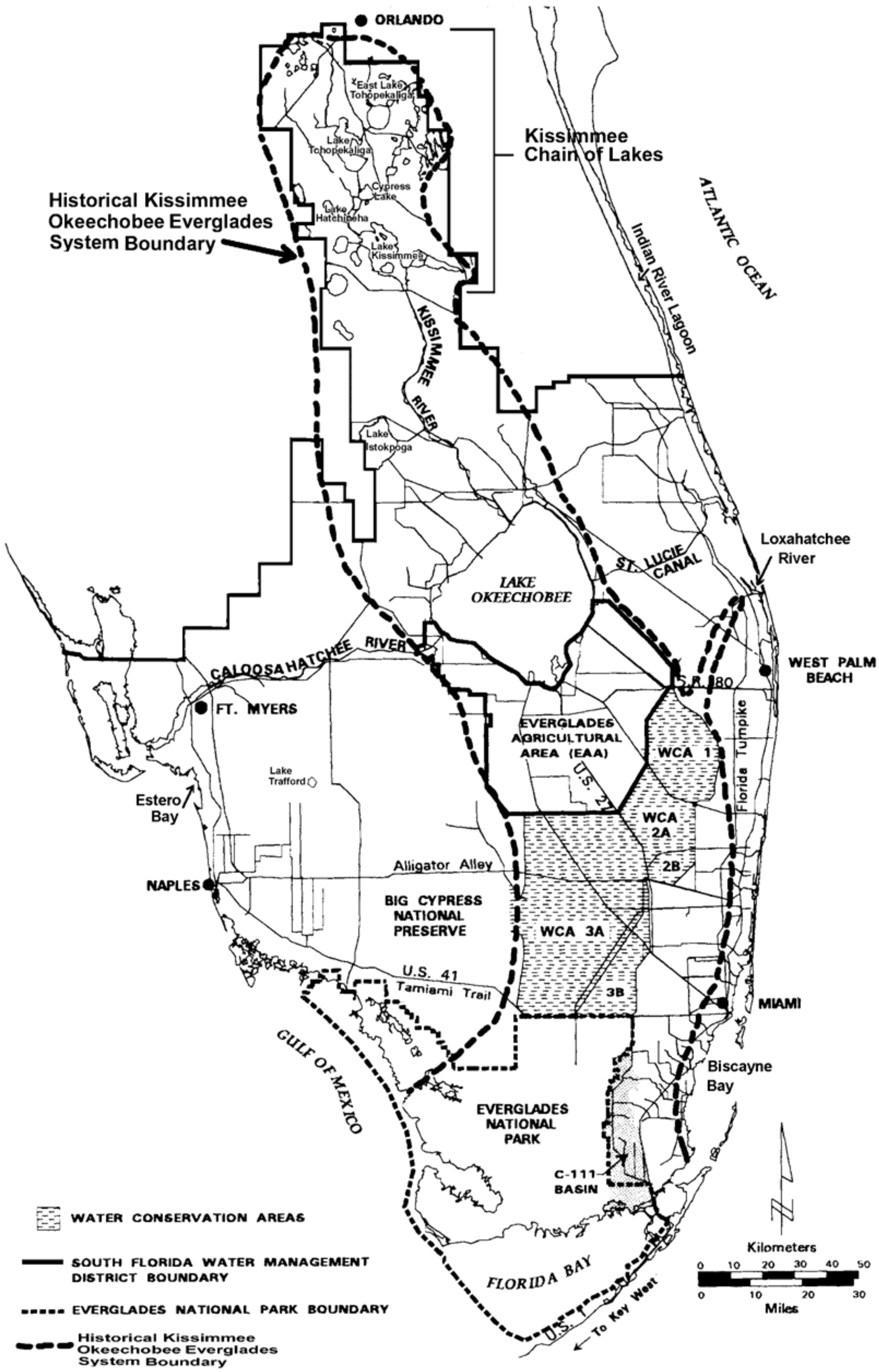

Figure 3. Kissimmee – Lake Okeechobee – Everglades (KOE) Ecosystem.

Today, the Kissimmee Chain of Lakes and Kissimmee River lie within the northern portion of the SFWMD's boundaries. The Kissimmee watershed contains an interconnected chain of large lakes (Lake Tohopekaliga, Cypress Lake, Lake Hatchineha and Lake Kissimmee) that extend from Orlando south to the Kissimmee River. This area also contains numerous small streams and rivers, most of which are eventually tributary to the Kissimmee River. Riparian plant communities of the Kissimmee River and its floodplain are recovering from channelization and drainage.

The dominant lake within south Florida is Lake Okeechobee and is often referred to as the "liquid heart" of south Florida. In its original condition, Lake Okeechobee was considerably larger than today and consisted of an extensive littoral zone marsh extending north, west and south of the lake.

Construction of the Herbert Hoover Dike and lowering of the lake has reduced it to its present size (730 square miles) creating an extensive littoral zone marsh community of about 98,000 acres inside the lake's levee system. These macrophyte communities provide important habitat for fish, wading birds and migratory waterfowl and are essential for maintaining the lake's ecological health. These communities are periodically stressed by extreme high and low lake levels, as well as by the spread of exotics (e.g., water hyacinth, torpedograss). Other major lakes located within the SFWMD include Lake Istokpoga in Highlands County and Lake Trafford located in Collier County (**Figure 3**).

Three major rivers in south Florida are the Caloosahatchee, St. Lucie and Loxahatchee Rivers that support important freshwater communities upstream and feed into highly productive coastal estuaries (**Figure 3**).

Below Lake Okeechobee, the vast wetlands of the Everglades historically extended more than 100 miles south to Florida Bay. All of the pond apple swamp forest and most of the sawgrass plain of the northern Everglades have been converted to farmland within the Everglades Agricultural Area (EAA). Also eliminated, is the band of cypress forest along the eastern fringe of the Everglades, which was largely converted to agriculture after this community was cut off from the remaining Everglades by the eastern levee of the Water Conservation Areas (WCAs). The remaining mosaic of sawgrass plains, aquatic slough and tree island areas located within the WCAs and Everglades National Park have been altered by changes in hydrology, soil subsidence, exotic plant invasion and nutrient inputs.

The problems of the Everglades extend downstream to the mangrove estuary and coastal basins of Florida Bay, where the mangrove forest mosaic and submerged aquatic vegetation show the effects of diminished freshwater heads and flows from upstream areas that periodically result in hypersaline conditions that affect estuarine resources. These effects are also exacerbated by a rise in sea level.

The upland pine and hardwood hammock communities throughout south Florida have historically had very little protection and have been the primary areas where development has occurred. Significant natural upland areas still exist in the Lake Wales Ridge, along the northwestern edge of the SFWMD boundary. Pinelands of the Atlantic coastal ridge were historically interspersed with wet prairies and cypress domes and dissected by "finger glades" watercourses that flowed from the Everglades to the coast. These remain only in small and isolated patches that have been protected from urban development.

Overall, the wetland systems that have been most seriously degraded and will receive the most benefit from proposed restoration efforts are: the Everglades peat forming marsh areas located within Water Conservation Areas 1, 2 and 3 including Shark River Slough located within Everglades National Park; the Everglades marl forming wet prairies including the rocky glades located within Everglades National Park; and 3) the mangrove estuaries and coastal basins of Florida Bay. Several other natural systems in south Florida already have restoration plans that have been developed, or are underway. These include: the Kissimmee River, where restoration is already in progress; the Indian River Lagoon and the Northwest Fork of Loxahatchee River and Estuary, where restoration plans are being developed; Lake Okeechobee, for which a plan is being developed to reduce phosphorus loads consistent with total maximum daily loads; and the Big Cypress National Preserve, where vegetation impacts and fixes are relatively minor compared to the Everglades.

MAJOR SURFACE WATER FEATURES

Kissimmee Basin and Chain of Lakes

Water bodies and wetlands together cover about a quarter of the Kissimmee watershed. The Kissimmee Chain of Lakes includes East Lake Tohopekaliga, Lake Tohopekaliga, Cypress Lake, Lake Hatchineha and Lake Kissimmee **(Figure 3).** Most wetland systems within the Kissimmee Basin drain into the Kissimmee River, and subsequently into Lake Okeechobee. The Kissimmee Basin is divided at the outlet of Lake Kissimmee (S-65) into upper and lower basins. The Upper Kissimmee Basin, located largely within Osceola County, is dotted with hundreds of lakes, ranging in size from less than an acre to over 55 square miles (Lake Kissimmee). Shingle Creek Swamp, Reedy Creek and Boggy Creek begin the headwaters of this system feeding into Lake Tohopekaliga and East Lake Tohopekaliga. Most of these interconnected lakes are shallow, with mean depths varying from 6 to 13 feet. Outflows from Lake Tohopekaliga and the Alligator Chain of Lakes drain into Cypress Lake, which in turn flows into Lake Hatchineha and then into Lake Kissimmee. Large herbaceous marshes surround Cypress Lake, the north end of Lake Hatchineha and the entire shoreline of Lake Kissimmee. Large areas of forested cypress and mixed hardwood swamps, as well as smaller pockets of herbaceous marsh surround the Alligator Chain of Lakes.

The drainage basins within the SFWMD boundary of Polk County can be divided into the portions above and below Lake Hatchineha. Above the lake, the relatively low-lying flat prairies and shallow lake systems of Lake Marion and Saddlebag Lake drain into Lake Kissimmee. Lake Marion overflows through an extensive forested wetland system into Lake Hatchineha, which discharges to Lake Kissimmee. Saddlebag Lake flows in a northwesterly direction through a series of small lakes into Big Gum Lake, which in turn overflows into Lake Pierce and subsequently into Lake Hatchineha.

Below Lake Hatchineha, there are the lake systems of Lake Weohyakapka and Arbuckle Lake. Lake Weohyakapka flows into Lake Rosalie via Weohyakapka Creek, which is surrounded by forested floodplains. Lake Rosalie then drains in a southeasterly direction into Tiger Lake, which flows into Lake Kissimmee. Arbuckle Lake drains in a southerly direction into the Kissimmee River.

Lake Istokpoga, Florida's fifth largest lake, located in Highlands County, drains into both the Kissimmee River through the Istokpoga Canal and C-41A and Lake Okeechobee via C-40 and C-41. The lake used to be surrounded by extensive wetlands, but now only has remnant marshes. Pasture now surrounds a large portion of the lake, and residential development has taken place on the southwest shore of the lake.

Originally, small streams or seasonal wetlands connected these lakes, so that substantial flow between lakes only occurred during major storm events. Today, canals and water control structures link most of the lakes together. The natural seasonal fluctuations in water levels are now regulated within limits established by water control "schedules."

The Lower Kissimmee Basin includes the tributary watersheds of the Kissimmee River between the outlet of Lake Kissimmee (S-65) and Lake Okeechobee. The Kissimmee River and Lake Istokpoga are the major surface water features in this basin.

Kissimmee River

The Kissimmee River (**Figure 3**) and floodplain has been highly altered from its original condition by construction of a major canal and water control impoundments. The Kissimmee River was originally a meandering river and floodplain with numerous oxbows extending 103 miles south from Lake Kissimmee to the north end of Lake Okeechobee. In the 1960s, the river was channelized into a 56-mile canal (C-38) by the U.S. Army Corps of Engineers (USACE) to improve flood protection within the watershed. Today the Kissimmee River is divided into five pools (pools A–E) by a series of combined locks and spillways. Water levels in each of these pools are managed according to a regulation schedule.

Efforts are underway today to restore the river and its headwaters to achieve a more natural flow and water level conditions in the river and floodplain. The Kissimmee River Restoration Project, which is underway, is designed to restore 43 miles of the river by redirecting flows through the historic river channel and restoring the ecological functions of the river/floodplain system. The approved plan is expected to restore 27,000 acres of floodplain wetlands and will benefit over 320 species of fish and wildlife including the endangered wood stork, snail kite and southern bald eagle. Environmental studies on the river are establishing a baseline for tracking expected changes and responses to the ecosystem as restoration projects move forward.

Lake Okeechobee

Lake Okeechobee and its watershed are key components of the Kissimmee – Okeechobee – Everglades (KOE) ecosystem. The lake covers 730 square miles and represents the second largest body of fresh water located wholly within the continental United States (**Figure 3**). The lake is shallow with a mean depth of only 9 feet located within south-central Florida. It has a surface water storage capacity of over one trillion gallons and represents the "liquid heart" of south Florida's water supply-flood control system. Major inflows to the lake include the Kissimmee River, Fisheating Creek and Taylor Creek/Nubbin Slough. The lake supports an extensive littoral zone (150 square miles) that provides important feeding and nesting habitat for fish, wading birds, migratory waterfowl, as well as the endangered Everglades snail kite. The lake is nationally renowned for its fishing (black bass and crappie) and supports a viable commercial and sportfishing industry (SFWMD, 2003b).

The lake is a direct source of drinking water for lakeside cities and towns and serves as a backup water supply for urban areas located along the Lower East Coast of Florida (**Chapter 9**). The lake provides irrigation water for the 700-square-mile EAA located south of the lake and represents a critical supplemental water supply for the Everglades during dry periods. Given these often-competing demands on the lake, management of the water resource is a major challenge.

Lake Okeechobee is the heart of the Central and Southern Florida Flood Control Project (C&SF Project) and is a key water storage feature of the region's interconnected aquatic ecosystem. It has multiple functions, including flood protection, agricultural and urban water supply, navigation, fisheries and wildlife habitat. As such, operation of the lake affects a wide range of environmental and economic issues. Lake operations must carefully consider the entire and sometimes conflicting needs of the regional water management system.

Lake water levels are regulated by a complex system of pumps and locks. The primary tool for managing lake water levels is the regulation schedule. The Water Supply and Environment (WSE) schedule was formally adopted by the USACE in July 2000. This schedule, designed to provide environmental benefits to the lake and downstream systems while protecting the region's water supply, uses climate forecasting and tributary hydrologic conditions to determine the volumes of water to release from the lake under flood control circumstances.

During extreme wet periods, large-scale regulatory releases may be required to protect the integrity of the levee system. Releases of this magnitude can be damaging to the downstream estuarine systems. The WSE schedule includes a series of "Best Management Zones," designed to provide a buffer or safety factor for making early or pulsed releases of lake water to downstream estuaries. These release patterns are called pulse releases because they mimic the pulse release associated with a rainfall event that would normally occur in an upstream watershed of the estuary. This release concept allows the estuary to absorb the freshwater release without drastic or long-term salinity fluctuations.

The *Adaptive Protocols for Lake Okeechobee Operations* (SFWMD, USACE, FDEP, 2003) spells out in detail how lake managers can meet the intent of the WSE schedule. Decisions regarding water releases from the lake are grounded in a set of "performance measures" (indicators of ecosystem health and water supply conditions) based on science and engineering.

Although Lake Okeechobee is a potentially large source of water, there are competing users of this water elsewhere within the Lake Okeechobee Service Area, as well as the Lower East Coast (LEC) and Lower West Coast (LWC) Planning Areas (**Chapters 8** and **9**). During periods of water shortage, the SFWMD implements water use restrictions to prevent serious harm to the water resources and to equitably distribute available water supplies to consumptive and nonconsumptive users. These types of restrictions may be used for the purpose of managing water supplies in Lake Okeechobee. The specific guidelines for implementing these water restrictions are provided in the Water Shortage Plan, Chapter 40E-21, F.A.C. As part of this overall plan, the Supply Side Management Plan provides protocol for implementing water use restrictions and management alternatives during declared water shortages. The specific method for implementing restrictions is determined through governing board order.

The supply-side methodology makes use of the concept of "share accounts" that represent the volumes of water available to different users of lake water with consideration for both drought severity and user demand. This methodology provides flexibility in dealing with short-term fluctuations in demand, accounts for all components of the lake water budget and incorporates consideration for many uses of lake water outside of agriculture and the Lower East Coast Service Areas (e.g. environmental deliveries, navigational requirements, etc.). The *Lake Okeechobee Supply-Side Management Plan* (SFWMD, 2002d) is implemented if the projected lake stage falls below 11.0 feet National Geodetic Vertical Datum (NGVD) at the end of the dry season, or below 13.5 feet NGVD at the end of the wet season (May 31).

Water quality analysis shows that the Lake Okeechobee watershed has contributed excessive phosphorus levels to the lake. In 2000, the Florida legislature enacted the *Lake Okeechobee Protection Act* (LOPA) (Sec. 373.4595, F.S.) to reduce phosphorus loading and implement long-term solutions based on the lake's goal of achieving a Total Maximum Daily Load (TMDL) of 140 tons/year as adopted by the FDEP in May 2001. Details of the LOPA are available in the Lake Okeechobee Surface Water Improvement and Management (SWIM) section near the end of this chapter.

The Everglades

Historically during wet periods, Lake Okeechobee discharged water over its southern rim into the Everglades. Originally, this vast sawgrass marsh extended south from Lake Okeechobee south to the peninsular tip of Florida, east to the coastal ridge and west to the Immokalee Ridge (roughly the border of the Big Cypress National Preserve) covering more than 4,500 square miles. Today, this vast mosaic of wetland plant communities has been reduced by almost 50 percent due to drainage and development. A large portion (more than 700,000 acres) of the original Everglades immediately south of Lake Okeechobee has been converted to agricultural lands, known as the Everglades Agricultural Area (EAA).

The Water Conservation Areas

South of Lake Okeechobee and the EAA, the C&SF Project has compartmentalized the Everglades into Water Conservations Areas (WCAs) 1, 2A, 2B, 3A and 3B located within Palm Beach, Broward and Miami-Dade counties (**Figure 3**). These five surface water impoundments (1,371 square miles) were developed to provide flood control, water storage and wildlife conservation benefits for the region. The WCAs contain the region's last remnants of the original sawgrass marshes, wet prairies and hardwood swamps located outside of Everglades National Park. The WCAs are managed as surface water reservoirs with a combined storage capacity of 1,882,000 acre-feet. Water Conservation Areas 2B and 3B primarily recharge and maintain groundwater levels in coastal areas to the east (Light and Dineen 1994).

Everglades National Park

Flows from WCA-3A and WCA-3B enter the northern boundaries of Everglades National Park through a series of water management structures and culverts located under Tamiami Trail (US 41). Much of this water enters the Park and flows in a southwest arc through Shark River Slough to Whitewater Bay and the Ten Thousand Islands area. Some of the water entering the Park is diverted to the east into South Dade Conveyance System and enters the Park via the L-31N Canal and Taylor Slough, as well as from the C-111 Canal where it sheetflows south into northeast Florida Bay.

Everglades National Park (**Figure 3**) is the largest remaining subtropical wilderness in the United States. The Park contains both temperate and tropical plant communities, including sawgrass prairies, mangrove and cypress swamps, pinelands and hardwood hammocks, as well as marine and estuarine environments. The Park is known for its abundant bird life, particularly large wading bird colonies including the roseate spoonbill, wood stork, great blue heron and a variety of egrets. Its abundant wildlife includes rare and endangered species, such as the American crocodile, Florida panther and West Indian manatee. It has been designated an International Biosphere Reserve, a World Heritage Site and a Wetland of International Importance, in recognition of its significance to all the peoples of the world (Ogden and Davis 1994).

Transitional wetland areas that were historically located along the eastern border of the Everglades are now urban or agricultural areas. In total, about 2.9 million acres of the Everglades wetlands has been transformed for human uses and three major wetlands types have been severely reduced in size. The Everglades that remains today has been significantly affected by construction and operation of the C&SF Project, a water management system of canals, structures and pumps that have altered natural patterns of water flow and storage. This and the loss of wetlands to developed areas have adversely affected food webs that support wading bird populations. The project also has conveyed nutrient runoff from the EAA and urban sources to natural areas, where undesirable shifts of biota have occurred. Changes in hydrology have altered both the extent and frequency of naturally occurring fires and provided areas suitable for the successful invasion of exotic species, such as melaleuca, Australian pine and Brazilian pepper. Hydrologic changes also have affected downstream estuarine systems that no longer receive historical quantities and timing of overland water flows.

Restoration of the remaining Everglades ecosystem requires research and an understanding of how the ecosystem functioned prior to man's intervention. Restoration focuses on improving upstream water quality and improving Everglades "hydropatterns—the timing, depth and flow of surface water across these wetlands. Restoring these natural hydropatterns depends on knowledge of original pre-canal drainage conditions, as well as an understanding of the soil, topographic and vegetation changes that have taken place since canal drainage began in the 1880s (Ogden and Davis, 1994).

Big Cypress National Preserve

To the west of WCA-3A lies the 729,000-acre Big Cypress National Preserve located primarily within Collier County. The Big Cypress Swamp occupies a large section of southern Hendry County, including part of the Big Cypress Seminole Indian Reservation. Cypress forests, small pine hammocks and marshes characterize the area. The name Big Cypress refers to the large size of this area, known for its vast stands of stunted pond cypress, as well as its cypress domes and strands that dominate this unique landscape. There are in excess of 100 species of plants and 20 species of animals in the Preserve listed by the state as endangered or threatened. From a hydrologic standpoint, the Big Cypress Preserve serves as a supply of fresh, clean water for the estuaries of the

Ten Thousand Islands area. The Big Cypress Preserve was set-aside in 1974 to ensure the preservation, conservation and protection of the natural scenic, floral, faunal and recreational values of the Big Cypress Watershed. The Big Cypress Preserve is home to nine federally listed species including the bald eagle and peregrine falcon. Five endangered birds, the snail kite, wood stork, Cape Sable seaside sparrow and red cockaded woodpecker nest in the Preserve. The endangered West Indian manatee and Florida panther and the threatened eastern indigo snake and American alligator also live in the Preserve. In addition, six state listed species inhabit the Preserve, the white-crowned pigeon, Florida sandhill crane, least tern, Everglades mink, Big Cypress fox squirrel and the black bear.

Other Surface Water Features (by County)

Martin, St. Lucie and Okeechobee Counties

The area now known as the Allapattah Flats was historically a series of sloughs that flowed from St. Lucie County southwest into Martin County through Barley-Barber Swamp and into Lake Okeechobee. Highways, railroads and drainage projects have modified this drainage pattern.

Another large wetland system, Cane Slough, is located immediately west of Interstate 95. This slough flows from the northwest to southeast and is a recharge area for the headwaters of the St. Lucie River. As a result, of channelization and dikes, Cane Slough now consists of isolated cypress areas, ponds and wet prairies.

The DuPuis Reserve and Pal-Mar Tract also contain significant wetland systems. The 21,875-acre DuPuis Reserve is located in southwestern Martin County and northwestern Palm Beach County. This site contains numerous ponds, wet prairies, cypress domes and remnant Everglades marsh. The Pal-Mar wetlands are primarily wet prairie ponds interspersed within a pine flatwood community.

Jonathan Dickinson State Park consists of 10,000 acres in southeast Martin County. It contains a variety of native uplands and wetlands, including pine flatwoods, sand pine scrub, palmetto prairies, cypress sloughs and domes, marsh and wet prairies. Acquisition efforts are underway in this area to purchase sufficient public lands to create a wildlife corridor that would connect Jonathan Dickinson State Park, Pal-Mar, Corbett Wildlife Management Area (in Palm Beach County) and the DuPuis Reserve.

The few large remaining inland wetland systems in St. Lucie County include the Savannas; wetlands associated with Five Mile, Ten Mile, Cow, Cypress and Van Swearingen Creeks; remnant portions of St. Johns Marsh; and the floodplain of the North Fork of the St. Lucie River. The Savannas, a freshwater wetland system located west of the Atlantic Coastal Ridge, is one of the most endangered natural systems in south Florida. Historically, the Savannas formed a continuous system stretching the length of the county.

Large tracts of forested and emergent wetlands are located in eastern Okeechobee County, creating a northwest to southeast system continuing into St. Lucie County.

Collier, Hendry and Lee Counties

Major wetland areas include the Okaloacoochee Slough, Fakahatchee Strand, the Big Cypress National Preserve and the Corkscrew Regional Ecosystem Watershed (CREW) lands. A number of these systems are relatively pristine wetland areas and are recognized as having national and regional importance (e.g., Big Cypress National Preserve, Corkscrew Swamp Sanctuary and Fakahatchee Strand). These wetland areas serve as important habitat for a wide variety of wildlife and have numerous hydrological functions. Before development of the region, inland areas were comprised of vast expanses of cypress and hardwood swamps, freshwater marshes, sloughs and flatwoods. Scattered among these systems were oak/cabbage palm and tropical hammocks, coastal strand and xeric scrub habitats. A large portion of the area contained seasonally flooded wetlands, with fresh water sheetflowing from the northeast to the southwest.

Okaloacoochee Slough is one of the two most important surface water flowways in Collier County, with Lake Trafford-CREW being the other. The headwaters of the Okaloacoochee Slough are in northern Hendry County. The slough extends southward to Collier County, where it eventually branches to the Fakahatchee Strand. Okaloacoochee Slough is composed largely of herbaceous plants with trees and shrubs scattered along its fringes and central portions. It provides habitat for a wide variety of wildlife, such as the endangered Florida Panther.

Fakahatchee Strand contains a diversity of plant communities, such as mixed hardwood swamps, cypress forest, prairies, hammocks, pine forest and pond apple sloughs. There are at least 30 species of plants and animals in the strand that are endangered, threatened or species of special concern.

The Corkscrew Regional Ecosystem Watershed (CREW) is a 60,000-acre project in Lee and Collier counties, consisting of Corkscrew Sanctuary, Corkscrew Swamp, Camp Keais Strand, Flint Pen Strand and Bird Rookery Swamp. Cypress forest, low pine flatwoods, hardwood hammocks, marshes, mixed swamps and ponds dominate the CREW lands. This system provides valuable habitat supporting at least 65 species of plants and 12 species of animals listed by the state as endangered or threatened.

Major wetland areas in Lee County include the Six Mile Cypress Slough and Flint Pen Strand, which are within CREW. The Six Mile Cypress Slough encompasses 2,000 acres in Lee County, dominated by cypress and interspersed with numerous ponds. The native plant communities fringing the slough are pine flatwoods, hardwoods and wet prairies. Heavy infestation of melaleuca has occurred in the southern one-third of the slough.

Glades and Charlotte Counties

The major wetland in western Glades County is Fisheating Creek. Fisheating Creek is an extensive riverine swamp system that forms a watershed covering hundreds of square miles. Fisheating Creek is the only free flowing tributary to Lake Okeechobee. The creek attenuates discharges from heavy storm events and improves water quality before the storm water enters the lake. The creek also serves as a feeding area for wading birds, such as the endangered wood stork, white ibis and great egrets, when stages in the marshes surrounding Lake Okeechobee are too high.

In eastern Charlotte County, a portion of Fred C. Babcock/Cecil M. Webb Wildlife Management Area and Telegraph Cypress Swamp cover nearly 10,000 acres. Both systems are diverse with a mixture of hydric pine flatwoods, cypress strands and marshes.

Major Lakes and Rivers

Rivers

The Kissimmee River was originally 103 miles in length until it was channelized in the 1960s into a 56-mile canal (C-38). The Kissimmee River is divided into five pools (pools A–E) by a series of combined locks and spillways. The water level in each of these pools is regulated according to a regulation schedule. The Kissimmee River Restoration Project, in progress, will backfill 22 miles of the C-38 Canal, directing flows through the historic river channel and restoring the ecological functions of the river/floodplain system. In the 1990s, backfilling began midway between S-65A and S-65B and will continue southward to S-65D.

The Caloosahatchee River was channelized in the 1800s and connected to Lake Okeechobee (**Figure 3**). The river floodplain has been altered by construction of a series of navigational locks and water control structures to artificially manage water levels and flows. Due to the need to manage water levels in Lake Okeechobee, large quantities of water are periodically released into the estuary.

The St. Lucie River lies in Martin and St. Lucie counties and includes the North and South Forks (**Figure 3**). These forks combine in the St. Lucie Estuary. Numerous creeks feed the St. Lucie River and Estuary in both Martin and St. Lucie counties. These include Danforth and Mapp Creeks, which are tributaries of the South Fork of the St. Lucie River downstream of the St. Lucie Canal. The Five and Ten Mile Creeks are the headwaters and tributaries to the North Fork of the St. Lucie River; and Willoughby, Bessey and Manatee Creeks enter directly to the St. Lucie Estuary.

The Loxahatchee River **(Figure 3)** is located in southern Martin County and northern Palm Beach County. The Northwest Fork of the Loxahatchee River and North Fork of the Loxahatchee River drain into the Loxahatchee Estuary. The Northwest Fork originates in the Loxahatchee Slough. The slough receives discharges from the C-18 Canal and runoff and groundwater inflow from adjacent uplands. Downstream from the slough, the Northwest Fork receives additional input from three major tributaries: Cypress Creek, Hobe Grove Ditch and Kitching Creek. The North Fork originates in Jonathan Dickinson State Park. Limestone Creek and Simms Creek connect to the Loxahatchee River Estuary.

The North Fork of the St. Lucie River and the Loxahatchee River have been designated as aquatic preserves by the State of Florida. The Northwest Fork of the Loxahatchee River is also a "National Wild and Scenic River." These designations are intended to preserve the biological, aesthetic or scientific values of these resources for the enjoyment of future generations.

The Northwest Fork of the Loxahatchee River was Florida's first Wild and Scenic River designated by the federal government. Natural tributaries to the Loxahatchee River system include the Loxahatchee Slough and North Fork of the River, Cypress Creek, Hobe Grove Ditch, Kitching Creek, Limestone Creek and Simms Creek.

In most of Palm Beach, Broward and Dade counties, the historical coastal rivers and streams, such as the Earman River, Hillsboro River, Snake Creek, Arch Creek, Miami River and Black Creek, have been channelized by construction of major drainage canals, although a few natural areas remain within these watersheds. A number of important river systems remain within Everglades National Park and the Ten Thousand Islands, including Taylor River, Shark River, Lostman's River and Turner River.

Major Lakes

The largest lake within the SFWMD is Lake Okeechobee (467,200 acres), which is discussed in a previous section of this chapter. Lake Kissimmee covers an area of 34,948 acres and represents the second largest lake within the District. Lake Kissimmee serves as the primary source of water for the Kissimmee River. Lake Istokpoga, at 27,692 acres, is the third largest lake within the District and provides flows to both the Kissimmee River and Lake Okeechobee. Some of the other major lakes located within the District include Lake Tohopekaliga (18,810 acres); East Lake Tohopekaliga (11,968 acres); Lake Weohyakapa (7,532 acres); and Lake Hatchineha (6,665 acres) all located within the Kissimmee Basin and Lake Trafford (1,494 acres), which is located in Collier County.

Natural lakes within the Upper East Coast (UEC) Planning Area include Lake Eden in the Savannas State Preserve, Mile Lake, which is west of the North Fork of the St. Lucie River in southern Port St. Lucie, and Banner Lake, which is south of State Road 708 in Hobe Sound. These lakes provide habitat for aquatic plants and animals and other wildlife that rely on open water during some portion of their life. They are not considered important sources of water supply for agricultural and urban uses in the planning area.

Man-made water bodies are also prevalent in the UEC Planning Area. The largest of these is the Florida Power & Light (FPL) Reservoir, which covers approximately 6,600 acres in western Martin County. Many small borrow pits and surface water management lakes were dug throughout the District for fill and to improve drainage in low-lying areas. These ponds are common in the newer residential and golf course communities.

Lake Trophic State

A lake can be classified according to its trophic state. Oligotrophic lakes have low levels of nutrients, good water clarity and low levels of plant and animal life. Mesotrophic lakes have moderate levels of nutrients, moderate water clarity and a moderate amount of plants and animals. High levels of nutrients, reduced water clarity and an abundance of aquatic plant and animal life characterize eutrophic lakes. Hypereutrophic lakes are those that often have a pea soup appearance from the amount of algae in the water column, the presence of algal mats and an overabundance of nutrients. As rotting plant material uses oxygen, aquatic animal life may die off from a lack of dissolved oxygen in the water. Eventually, the mucky bottom of the lake fills up with sediments and converts into a marsh. Eutrophication is a natural process; however, human activities can accelerate this process (cultural eutrophication).

A decrease in nutrients to the lake systems should slow eutrophication. In the 1970s, a number of major lakes were significantly degraded by nutrients that originated from sewage treatment plants and from untreated non-point urban and agricultural sources. When the nutrient sources were identified and consequently reduced or eliminated, the water quality in these lakes improved. Better water quality in the Upper Kissimmee Basin may lead to improved quality in the Lower Kissimmee Basin and Lake Okeechobee.

COASTAL RESOURCES

Coastal resources include barrier islands, coastal ridge, wetlands and estuarine systems.

Barrier Islands

Barrier islands play important roles in providing habitat for a wide variety of tropical, native and endemic plants; shorebird and wildlife species protect the mainland from major storm events and act as a buffer for sensitive estuarine areas. These low lying, narrow strips of sand also play an important role in the region's tourism economy by attracting visitors to the beaches.

Barrier islands typically occur as low-lying areas of sand, mangrove peat deposits and coral rock that exist adjacent to the Atlantic Ocean or Gulf of Mexico. Along the east coast of Florida, these islands form an almost continuous chain that extends from the state line north of Jacksonville to Biscayne Bay and continues south through the Florida Keys to the Dry Tortugas. Barrier islands also form a chain that extends from northern Lee County to southern Collier County and then merges with the "Ten Thousand Islands" area of coastal mangrove forests and islands that continues southward to Florida Bay. The seaward edges of the islands generally support a coastal dune community, which includes salt and drought-tolerant species. Behind the dune community, cabbage palm, saw palmetto, oaks and sea grape are present. The shoreward edge of the islands typically supports mangrove wetlands. Much of the natural plant and animal communities of these islands has been lost to development.

Hutchinson Island is a low barrier island located along the eastern shoreline of Martin and St. Lucie counties. The eastern edge of the island supports a coastal dune community, which includes salt and drought-tolerant species. West of the dune community, cabbage palm, saw palmetto, oaks and sea grape are present. The western edge of the island supports mangrove wetlands.

Florida Keys

The Florida Keys are a limestone island archipelago extending southwest over 200 miles from the southern tip of the Florida mainland to the Dry Tortugas, 70 miles west of Key West. They are bounded on the north and west by the relatively shallow waters of Biscayne Bay, Barnes and Blackwater Sounds, Florida—all areas of extensive mud shoals and seagrass beds—and the Gulf of Mexico. Hawk Channel lays to the south, between the mainland Keys and an extensive reef tract 5 miles offshore. The Straits of Florida lie beyond the reef, separating the Keys from Cuba and the Bahamas.

The Keys are made up of over 1,700 islands encompassing about 103 square miles. They are broad, have a shoreline length of 1,865 miles and are inhabited from Soldier Key to Key West. Key Largo and Big Pine Key are the largest islands. The Keys are frequently divided into three regions: 1) the Upper Keys, north of Upper Matecumbe Key; 2) the Middle Keys, from Upper Matecumbe Key to the Seven Mile Bridge; and 3) the Lower Keys, from Little Duck Key to Key West.

Coastal Ridge and Wetlands

Coastal mangrove forests and salt marshes largely dominated the coastline of south Florida prior to development. Immediately behind the mangrove fringe, a coastal ridge is present along the edge of the mainland that forms a 1-mile to 3-mile-wide area dominated by sand pine, saw palmetto, scrub oaks and other xeric plant species. Wetland depressions often occurred further west of the coastal ridge, often forming continuous systems that extend for many miles. The Savannas, a remnant freshwater coastal wetland system, is located immediately west of the coastal ridge in Martin and St. Lucie counties. Similar systems of interconnected freshwater lakes and wetlands existed historically throughout much of the length of Palm Beach County.

Estuarine Systems

Coastal areas are dominated by large estuarine systems where the waters of the Atlantic Ocean or Gulf of Mexico mix with the freshwater inflows from numerous river systems, sloughs and overland sheet flow. Shallow bays, extensive seagrass beds and sand or mud flats characterize these estuarine areas. Extensive mangrove forests dominate undeveloped areas of the shoreline.

Several large open water estuarine systems, Charlotte Harbor, Pine Island Sound, the Caloosahatchee River estuary, Estero Bay, St. Lucie Estuary, Indian River Lagoon, Lake Worth Lagoon, Biscayne Bay, Whitewater Bay and Florida Bay occur within the District. Other associated habitats are high salt marshes and riparian fringing marshes. These estuaries provide important habitat for threatened and endangered species and support commercial and recreational fisheries. More than 40 percent of Florida's rare, endangered or threatened species are found in south Florida estuaries. One of the most renowned is the West Indian manatee, which depends on a healthy seagrass community as its major food source. The southern bald eagle and American crocodile also rely largely on the estuary as its feeding grounds.

Coastal areas subject to tidal inundation support extensive mangrove forests and salt marsh areas. Coastal mangroves protect against erosion from storms and high tides, and assimilate nutrients from flowing water to produce organic matter (leaves), which forms the base of the estuarine food chain. Mangroves and salt marsh communities serve as important nursery and feeding grounds for many economically important species of finfish and shellfish, which in turn support migratory waterfowl, shore bird and wading bird populations. These brackish water communities were once commonly distributed along the entire coastline, but are now found in greatest abundance in southwest Collier County and southern Lee County. The Ten Thousand Island region dominates the southern portion of Collier County and represents one of the world’s largest remaining intact mangrove forests.

Many of south Florida’s estuary areas are contained in aquatic preserves, such as Matlacha Pass, Pine Island Sound, Charlotte Harbor, Estero Bay, Rookery Bay, St. Lucie River, Loxahatchee River, Lake Worth Creek and Biscayne Bay. Florida Bay is included within Everglades National Park and southern Biscayne Bay is part of Biscayne National Park.

Indian River Lagoon/St. Lucie Estuary

The Indian River Lagoon extends about 155 miles through six coastal counties from Ponce De Leon Inlet in Volusia County southward to the Jupiter Inlet in Palm Beach County. Within the SFWMD boundaries, the Indian River Lagoon encompasses approximately 48 square miles and includes the Indian River Lagoon proper from Fort Pierce to Stuart, the St. Lucie Estuary, Hobe Sound and Jupiter Sound. The Indian River Lagoon watershed incorporates approximately 1,120 square miles (20 surface water management basins). Land uses within this watershed include high-density urban, extensive citrus operations and large stretches of improved pasture.

An estimated 4,300 species of plants and animals have been documented from the Indian River Lagoon according to the Surface Water Improvement and Management (SWIM) Plan that was jointly developed by St. Johns River Water Management District (SJRWMD) and South Florida Water Management District (SFWMD) (SJRWMD and SFWMD, 2002) making it the most diverse estuary in North America.

The St. Lucie Estuary is located in the southern region of the Indian River Lagoon in Martin and St. Lucie counties. The St. Lucie watershed encompasses about 781 square miles and is divided into five major basins and several small basins. The western basins are predominantly agricultural with about 70 percent of land in citrus and improved pasture. The two eastern basins (North St. Lucie and Tidal) are urban with about 45 percent of the land devoted to agricultural activities.

The St. Lucie Estuary is divided into three sections: the North Fork, the South Fork and the middle estuary. The North Fork is about 4 miles long with a surface area of 4.5 square miles. Depths range from 10 feet in the central portion to 20 feet at its juncture with the South Fork. The North Fork is designated as an aquatic preserve. The South Fork has about half the surface area of the North Fork, and is relatively shallow except for an 8-foot navigation channel. This channel is part of the Okeechobee Waterway, which links Stuart with Fort Myers through Lake Okeechobee and the Caloosahatchee River. The middle estuary begins at the confluence of the North and South Forks and continues to Hell Gate Point near the Indian River Lagoon proper.

Loxahatchee River and Estuary

The Loxahatchee River and Estuary and its upstream watershed are located along the southeastern coast of Florida within the Lower East Coast and Upper East Coast planning areas. This watershed consists of an area of approximately 210 square miles, is located within northern Palm Beach and southern Martin counties, and connects to the Atlantic Ocean via the Jupiter Inlet, near Jupiter, Florida. The Loxahatchee Estuary central embayment is located at the confluence of three major tributaries—the Northwest Fork, the North Fork and the Southwest Fork. The Northwest Fork originates at the G-92 Structure in northern Palm Beach County, flows north, enters Martin County, continues north and bends east through Jonathan Dickinson State Park (JDSP), and then flows southeast through the central embayment. The Atlantic Coastal Ridge in Eastern Martin County defines the headwaters of the North Fork, which flows south-southeast into the central embayment. All but one mile of the Southwest Fork has been channelized to form the C-18 Canal (C-18), which flows northeast through Palm Beach County to discharge into the central embayment. The central embayment connects to the Atlantic Ocean through Jupiter Inlet.

The Loxahatchee River and upstream floodplain are unique regional resources in several ways. The river has often been referred to as the “last free flowing river in southeast Florida.” In May 1985, based on its natural scenic qualities, diverse native plant and wildlife communities, and in order to preserve the natural landscape, a 7.5-mile reach of the Northwest Fork of the Loxahatchee River was federally designated as Florida's first Wild and Scenic River. In addition, different portions of the river and estuary are designated as an aquatic preserve, Outstanding Florida Waters and a state park. The Northwest Fork represents one of the last vestiges of native cypress river-swamp within southeast Florida. Large sections of the river’s watershed and river corridor are included within JDSP, which contains outstanding examples of the region’s natural habitats.

Along the river and within the park is coastal sand pine scrub, a biological community so rare it is designated “globally imperiled.” The watershed is unique in that it contains a number of natural areas that are essentially intact and in public ownership. These areas include the J.W. Corbett Wildlife Management Area, JDSP, Hungryland Slough Natural Area, Loxahatchee Slough Natural Area, Hobe Sound National Wildlife Refuge, Juno Hills Natural Area, Jupiter Ridge Natural Area, Pal-Mar, Cypress Creek and the Atlantic Coastal Ridge. These natural areas contain pinelands, xeric oak scrub, hardwood hammock, freshwater marsh, wet prairie, cypress swamp, mangrove swamps, seagrass beds, tidal flats, oyster beds and coastal dunes. A total of 267 animal species have been observed in and along the river and estuary (FDEP and SFWMD, 2000). The cypress river swamp community supports a number of species that have been identified as endangered, threatened or species of special concern by the Florida Fish and Wildlife Conservation Commission (FWC), or listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). The Loxahatchee River watershed also contains managed agricultural lands and urban areas.

Water levels in the rivers and canal systems are managed to provide for drainage of land and storage of water during the wet season and adequate conveyance capacity to protect lives and property in surrounding upland residential areas from flood damage during severe storm events. The amount of water that can be stored in the basin is limited due to the lack of sufficient storage capacity. For this reason, water must be discharged to tide in order to provide flood protection within the basin.

Flows in the Loxahatchee River have been highly altered due to drainage—specifically, construction of the C-18 and drainage of the Loxahatchee Slough. The long-term decline in the extent and health of the freshwater floodplain swamp community along the upstream portion of the Northwest Fork appears to be linked to hydrologic alterations of the river and its watershed, as well as past dredging activities in the estuary and Jupiter inlet. Combined, these two factors have resulted in reduced freshwater flows to the river, lowering of the groundwater table and increased saltwater intrusion of the floodplain swamp community during dry periods. Sufficient freshwater flows are required during the dry season to protect the existing cypress community from further degradation and loss of natural function.

Caloosahatchee River and Estuary

The Caloosahatchee River and Estuary and its upstream watershed are located within Lee, Hendry and Glades counties (**Figure 3**). The watershed drains an area of over 1,300 square miles extending 66 miles from Lake Okeechobee to the mouth of the Caloosahatchee Estuary (San Carlos Bay). The Caloosahatchee River (C-43), along with the St. Lucie Canal (C-44) are important components of the C&SF Project and are used primarily for regulatory releases from Lake Okeechobee when lake levels exceed the lake regulation schedule. In addition to regulatory discharges for flood protection, the river also receives water deliveries from the lake for river navigation and water supply for agriculture and urban users.

The Caloosahatchee Estuary is a large estuarine ecosystem where the waters of the Gulf of Mexico mix with the freshwater inflows from the river, sloughs and overland sheet flow from the upstream basin. A shallow bay, extensive seagrass beds and sand flats, characterizes the estuary. Extensive mangrove forests dominate undeveloped areas of the shoreline. The tidal portion of the river includes parts of Lee and Charlotte counties. The estuary length between the Franklin Lock and Shell Point is 26 miles and is bordered by Fort Myers on the south shore and Cape Coral on the north shore. The estuary is an important nursery ground for many commercially and recreationally important fish and shellfish species. The estuary also provides foraging areas and wetland habitat for a large number of Florida's rare, endangered and threatened species. Hydrologic alterations of the watershed have dramatically changed the natural quantity, quality, timing and distribution of flows delivered to the downstream estuary. Large, unnatural freshwater releases from the lake through the C-43 have altered the estuarine salinity gradient and transport significant quantities of sediment to the estuary. Biota within the Caloosahatchee Estuary and near-shore seagrass beds has been impacted by these high volume discharges.

Estero Bay

The Estero Bay watershed covers an area of 462 square miles and includes central and southern Lee County and parts of northern Collier and western Hendry counties. The principal freshwater inflows come from Hendry Creek, Mullock Creek, Estero River, Spring Creek and the Imperial River. Coastal portions of the watershed are urbanized and include the City of Fort Myers, Bonita Springs and the City of Fort Myers Beach. The watershed includes all of Estero Bay, most of which lays within the Estero Bay Aquatic Preserve and adjacent barrier islands. Hendry Creek, Mullock Creek, the Estero River, areas of Corkscrew Swamp, Spring Creek and the Imperial River are major surface water features in the basin.

Estero Bay (**Figure 3**) is defined as a long, narrow and very shallow body of water, with its northwestern border beginning at Bowditch Point on Estero Island, and reaching as far south as Bonita Beach. Estero Island, Black Island, Long Key, Lover's Key and Big Hickory Island are the barrier islands that separate the Bay from the Gulf of Mexico. The flora and fauna of the bay and its watershed are varied and abundant and include many state and federal-listed species, such as the West Indian manatee, loggerhead sea turtle, Florida panther, bald eagle, big cypress fox squirrel, red-cockaded woodpecker and snowy plover. The mangrove-lined shores and islands of the bay contain five rookeries or roosting areas that support brown pelicans, frigate birds, herons, egrets, cormorants and ibis.

Population growth in the Estero Bay Watershed has been rapid, posing a threat to sensitive natural resources in the bay and watershed. Urban land use in the basin is primarily located in the western developed corridor, the areas around Florida Gulf Coast University, Bonita Springs and western Immokalee. The major wetland and associated upland systems are located within the central and eastern parts of the basin, while the agricultural uses are located on the boundaries and between the large wetland systems.

Biscayne Bay

Located along the coast of Miami-Dade and northeastern Monroe County, Biscayne Bay comprises a marine ecosystem of about 428 square miles, and a watershed area of about 938 square miles. This subtropical estuary is designated as an "Outstanding Florida Water and an Aquatic Preserve" under Florida Statutes.

The bay can be divided intro three general areas, north, central and south Biscayne Bay. The north Biscayne Bay extends from Dumfoundling Bay south to the Rickenbacker Causeway. This area of the bay retains the most estuarine habitat found in the bay but it is also the most altered by dredging and bulkheading. Roughly, 40 percent of the area is too deep or too turbid to support a productive estuarine ecosystem. The remaining shallow areas contain highly productive seagrass beds. Manatee grass is extensive and serves as habitat for a diverse and popular fishery.

In contrast, central Biscayne Bay, extending from Rickenbacker Causeway south to Black Point, is more of a marine system that is heavily influenced by daily tidal flushing. Estuarine areas are limited to near shores areas close to major sources of freshwater inflow (canals). Seagrass meadows are extensive, in which turtle grass is dominant. This is a highly productive pink shrimp area, supporting a commercial fishing industry. A narrow band of mangrove-forested coastal wetlands begins at Matheson Hammock Park and extends southward along the shoreline.

Southern Biscayne Bay extends from Black Point to Jewfish Creek and includes Biscayne National Park, a sanctuary for the Florida spiny lobster. Card and Barnes Sounds are part of the Florida Keys National Marine Sanctuary. This area is most profoundly affected by a reduction in historical freshwater flows. This area of the bay tends to become hypersaline during periods of low rainfall. Freshwater wetlands have been significantly reduced and a transition to mangrove species is occurring.

Historically its clear water and its diverse and productive communities of seagrass, corals and sponges characterized Biscayne Bay. Prior to settlement, mangroves and coastal wetlands rimmed the bay. Freshwater flowed through transverse glades, over shallow falls of the coastal ridge. Groundwater flow was sufficient to cause upwelling fresh enough to drink. Oyster bars and estuarine species like red and black drum were common.

Overall, Biscayne Bay shows increasing signs of distress; declines in fisheries, increased pollution and dramatic changes in nearshore vegetation. Intensive development of the watershed has altered the natural cycle of freshwater inflows into the bay. Northern and central Biscayne Bay are strongly affected by the urban development associated with the growth of Miami. Southern Biscayne Bay is influenced by drainage from the Everglades, which has been altered by canals and agricultural activities. The opening of inlets and further channelization has contributed to the bay's transition from a freshwater estuary to a marine lagoon. Today, the bay is a pulsed system that alternates between marine conditions and extreme low salinities near the discharges of 19 major canals. Scientists have observed changes in fish diversity and abundance with a shift towards marine species over time. Red and black drum populations are no longer sustainable and oysters are not common. Restoration and preservation of Biscayne Bay and Biscayne National Park are dependent on a comprehensive understanding of the linkages between the hydrologic system and the bay ecosystem, and of the natural versus human-induced variability of the ecosystem.

Florida Bay

Between the southern edge of the Everglades and the Florida Keys lies a large, shallow, subtropical estuary called Florida Bay. This triangular shaped estuary, of about 850 square miles, is the largest estuary in Florida and the largest body of water within the Everglades National Park. Because the average depths of the mud flats of the bay are only about 3 feet, sunlight reaches the bottom and supports the growth of seagrass beds. Plants, such as turtle grass, horned pondweed and manatee grass, stabilize the mud flats. Seagrass beds serve as nursery areas, feeding grounds and refuges for many species. A number of different species of algae also live there. Exposed at low tide, the mud flats of Florida Bay provide a valuable feeding area for a number of birds.

Until recently, this subtropical estuary was noted for its clear, warm waters, lush seagrass beds and outstanding fishing. However, starting in the late 1980s, dramatic changes in the ecology of Florida Bay became evident. These changes included the widespread death of seagrass beds, turbid water associated with this die-off, large and sustained blooms of algae and population reductions in pink shrimp, sponges, lobster, recreational game fish and wading birds. The Comprehensive Everglades Restoration Plan (CERP) Florida Bay / Florida Keys Feasibility Study (discussed later in this chapter) will ultimately provide a recommended plan of action to restore Florida Bay.

Threatened and Endangered Species

The U.S. Fish and Wildlife Service (USFWS), has identified 18 federally listed plant and animal species that would likely be affected by changes in water management practices (**Table 1**). Of the listed species, critical habitat has been designated for the West Indian manatee (*Trichechus manatus*), the snail kite (*Rostrhamus sociabilis plumbeus*), the Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) and the American crocodile. For a description of these critical habitat geographic designations and a complete species description, taxonomy, distribution, habitat requirements, management objectives and recovery status, see the USFWS web site available from: http://www.fws.gov. A complete listing of all the federally listed threatened and endangered plant and animal species occurring or thought to occur within the study area is also available from this web site. The Florida Fish and Wildlife Conservation Commission (FWC) provide information on state-listed species (**Table 1**).

Appropriate hydrology is not just an issue for the plant communities, but also for the associated wildlife, including endangered and threatened species and species of special concern. Species composition, distribution and abundance are influenced by the annual pattern of rainfall, water level fluctuations, fire, occasional hurricanes, frosts and freezes.

Alterations in water depth and/or hydroperiod that result in changes to vegetative composition densities and diversity may lead to the degradation of fish and wildlife habitat. One of the causes of melaleuca infestation is a decrease in water table levels, which, when a seed source is present, can result in monotypic stands of tightly packed trees that have the potential to cause a localized decrease in biodiversity.

Wetland vegetative productivity usually exceeds that of other habitat types. Reduction in size of a wetland reduces food production at the bottom of the food chain. Alterations of the seasonal wet and dry pattern can also cause impacts. “The life cycle of many species is tied to this cycle. Wood storks, for example, are unable to successfully fledge their young without the dry season concentration of food. Anything that interferes with the cycle, too much water in the dry season or not enough in the wet season, tends to reduce fish and wildlife populations.” (University of Florida, 1982)

Table 1. Threatened and Endangered Plant and Animal Species Found in the Lower East Coast Planning Area.

Scientific Name	Common Name	USFWS[a]	FWC[a]
Mammals			
Trichechus manatus	West Indian Manatee	E[b]	E[b]
Felis concolor coryi	Florida panther	E	E
Mustela vison evergladensis	Everglades mink		T
Birds			
Rostrhamus Sociabilis plumbeus	snail kite	Eb	E
Mycteria americana	wood stork	E	E
Ammodramus maritimus mirabilis	Cape Sable seaside sparrow	Eb	E
Ammodramus savannarum floridanus	Florida grasshopper sparrow	E	E
Picoides borealis	red-cockaded woodpecker	E	T
Haliaeetus leucocephalus	bald eagle	T	T
Polyborus plancus (borealis)	Audubon's crested caracara	T	T
Aphelocoma coerulescens	Florida scrub jay	T	T
Grus canadensis pratensis	Florida sandhill crane		T
Ajaia ajaia	roseate spoonbill		SSC
Aramus guarauna	limpkin		SSC
Egretta caerula	little blue heron		SSC
Egretta thula	snowy egret		SSC
Egretta tricolor	tricolored heron		SSC
Eudocimus albus	white ibis		SSC
Falco peregrinus tundrius	Arctic peregrine falcon		SSC
Speotyto cunicularia	burrowing owl		SSC
Reptiles and Amphibians			
Crocodylus acutus	American crocodile	Eb	E
Drymarchon corais couperi	Eastern indigo snake	T	T
Gopherus polyphemus	gopher tortoise		SSC
Pituophis melanoleucus mugitus	Florida pine snake		SSC
Tantilla oolitica	Miami black-headed snake		SSC
Rana capito	gopher frog		SSC
Invertebrates			
Liguus fasciatus	Florida tree snail		SSC
Heraclides aristodemus ponceanus	Shaus' swallowtail butterfly		E
Plants			
Cucurbita okeechobeensis	Okeechobee gourd	E	
Amorpha crenulata	crenulate lead plant	E	
Euphorbia deltoidea	deltoid spurge	E	
Galactia smallii	Small's milkpea	E	
Polygala smallii	tiny polygala	E	
Euphorbia garberi	Garber's spurge	T	

[a] E=Endangered; T=Threatened; SSC=Species of special concern
[b] Designated critical habitat

Flooding of wetlands during the summer months initiates the production of aquatic plants, such as attached algae (periphyton) and macrophyte communities. Small fish and invertebrates consume these plants. Maximum numbers of fish and invertebrates occur near the end of the wet season. As marsh water levels decline during the dry season, these organisms are concentrated into smaller and smaller pools of water where they become easy prey for wading birds and other species of wildlife. Fish and invertebrates are the major dietary components of south Florida wading and water bird populations. Wading bird nesting success is highly dependent upon the natural seasonal fluctuations in hydroperiod of these marsh systems and the concentration of food resources. Biological factors, such as predation, competition and feeding habits also play important roles in configuring wildlife communities.

PROTECTION OF NATURAL SYSTEMS

Wetlands

Wetlands are transitional lands between uplands and aquatic systems (water bodies) and are typically defined by vegetation, soils and hydrology. Chapter 62-340, F.A.C., provides the statewide methodology for delineating wetlands in Florida. In part, the Code includes the following definition of wetlands:

> Those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils.

Functions and Values of Wetlands

Wetlands within the SFWMD planning regions include swamps, marshes, bayheads, cypress domes and strands, sloughs, wet prairies, riparian wetland hardwoods and mangrove swamps. Wetlands perform a number of valuable hydrologic and biological functions. Hydrologic functions performed by wetlands include receiving and storing surface water runoff. This is important in controlling flooding, erosion and sedimentation. Surface water that enters a wetland is stored until the wetland overflow capacity is reached and water is slowly released downstream. As the flow of water is slowed by wetland vegetation, sediments in the water (and chemicals bound to the sediments) drop out of the water column, improving water quality.

Wetlands also function hydrologically as groundwater recharge-discharge areas. Wetlands may recharge the groundwater when the water level of a wetland is higher than the water table. Conversely, groundwater discharge to wetlands may occur when the water level of the wetland is lower than the water table of the surrounding land.

Biological wetland functions include providing habitat for fish and wildlife, including organisms classified as endangered, threatened or species of special concern.

Some species depend on wetlands for their entire existence, while other semiaquatic and terrestrial organisms use wetlands during some part of their life cycle. Their dependence on wetlands may be for overwintering, residence, feeding and reproduction, nursery areas, den sites or corridors for movement. Wetlands are also an important link in the aquatic food web. They are important sites for microorganisms, invertebrates and forage fish, which are consumed by predators, such as amphibians, reptiles, wading birds and mammals.

Types of Wetlands

Inland or freshwater wetlands within the planning regions can be grouped into three major categories based on hydroperiod: permanently flooded or irregularly exposed; seasonally or semipermanently flooded; and temporarily flooded or saturated. The Florida Land Use and Cover Classification System (FLUCCS) was used to delineate wetland systems within the regional planning areas. The hydroperiod categories were created by combining FLUCCS coverage classifications with the National Wetlands Inventory hydrologic classifications. The hydrologic categories are broadly defined as:

- **Permanently Flooded or Irregularly Exposed.** Water covers the substrate throughout the year in all years or the substrate is exposed by tides less often than daily. The category corresponds to lakes, reservoirs, embayments and major springs.
- **Seasonally or Semipermanently Flooded.** Surface water persists throughout the rainy season and much of the dry season in most years. When surface water is absent, the water table is at or very near the land surface. Seasonally flooded soils are saturated. The category corresponds to swamps, sloughs, mixed wetland hardwoods, cypress, wetland forest mixed, freshwater marshes, sawgrass and or cattail, wet prairies, emergent and submergent aquatic vegetation.
- **Temporarily Flooded or Saturated.** Surface water is present for brief periods during the rainy season, but the water table usually lies below the soil surface for most of the year. Plants that grow in both uplands and wetlands are characteristic of this water regime. The substrate is saturated to the surface throughout the rainy season or for extended periods during the rainy season in most years. Surface water is seldom present. The category corresponds to cypress-pine-cabbage palm, wet prairie-with pine, intermittent ponds, pine-mesic oak, Brazilian pepper, melaleuca and wax myrtle-willow.

Inland wetlands within the District can be grouped into three major categories: forested, scrub shrub and herbaceous wetlands. These classes were generalized from the National Wetlands Inventory (NWI), a branch of the U.S. Fish and Wildlife Service. The NWI is a nationwide wetland mapping system.

Freshwater-forested wetland communities include cypress, cabbage palm, mixed hardwood and bayheads. Scrub shrub wetland communities can be found in a number of different habitat and hydroperiod ranges. Shrubs, such as wax myrtle and St. Johns Wort, which are indicative of temporarily flooded soil, often border the wetter herbaceous marshes and prairie ponds. In the wetter areas, willow and small bay are the dominant shrub species. Herbaceous (emergent) wetlands can generally be referred to as marsh. There are also sloughs, wet prairies and prairie ponds.

Uplands

Native uplands are non-wetland areas with intact ground cover, understory and canopy. Native uplands include longleaf and slash pine forests, live oak hammocks, sand pine scrub, cabbage palm, turkey oak, hardwood forest, palmetto prairies, xeric oak and hardwood hammocks and dry prairie grasslands. With few exceptions, the functions and values attributed to wetlands also apply to upland systems. Upland and wetland systems are ecological continuums, existing and adapting to geomorphic variation. The classification of natural systems is artificial and tends to convey a message that they survive independently of each other. In reality, wetland and upland systems are interdependent on each other. To preserve the structure and functions of wetlands, the linkage between uplands and wetlands must be maintained.

Function and Values of Uplands

Uplands serve as recharge areas, absorbing rainfall into soils to be used by plants or stored underground within the aquifer. Groundwater storage in upland areas reduces runoff during extreme rainfall events, while plant cover reduces erosion and absorbs nutrients and other pollutants that might be generated during a storm. Uplands often have groundwater storage available in the Surficial Aquifer System (SAS). Rainfall infiltrates the surface soils and becomes partly used by plants through evapotranspiration, and the remainder percolates to groundwater storage. Upland vegetative areas also provide climate moderation, noise barriers, wildlife habitat and recreational resources.

Pine flatwoods are an important upland community throughout the region. These plant associations are characterized by a low, flat topography and poorly drained, acidic, sandy soils. Under natural conditions, fire maintains flatwoods as a stable plant association. However, when the natural frequency of fire is altered by increased drainage and the construction of roads and other fire barriers, flatwoods can succeed to other community types. The nature of this succession depends on soil characteristics, hydrology, available seed sources or other local conditions. Flatwoods are important habitat for a number of threatened or endangered species, such as the Florida Panther, eastern indigo snake, red-cockaded woodpecker and gopher tortoise. Pine flatwoods have greater richness of vertebrate species than either sand pine scrub or dry grass prairies. Upland communities, particularly, pine flatwoods are seriously threatened by development in the Upper East Coast (UEC) Planning Area.

Flatwood communities are divided into two types: dry and hydric. An open canopy of slash pine with an understory of saw palmetto characterizes dry flatwood communities. However, dry flatwoods are located in a slightly higher elevation in the landscape and are rarely inundated. Hydric flatwood communities (wetlands) are vegetatively similar to dry flatwoods. Large areas of flatwoods are found throughout Hendry and Lee counties, as well as portions of Charlotte, Glades and Collier counties. Upland flatwoods are the native habitats most affected by the expansion of citrus into southwest Florida.

The Longleaf Pine-Turkey Oak Hills ecological community occurs nowhere else in the SFWMD except in eastern Polk and northern Highlands counties. This community occurs on rolling land. Water moves rapidly through the soils. There are several variations of this community. Mature natural stands of trees have scattered longleaf pine as an overstory. Areas where pines have been removed are predominantly oaks. Ground cover is scattered and numerous bare areas are noticeable. This community is influenced by fire, heat and drought. The natural vegetation is adapted to withstand the effects of occasional fire. Without the occurrence of fire, the longleaf pine cannot withstand the invasion of hardwood species and would change into an upland hardwood hammock. In this habitat, water moves rapidly through the soil to the aquifer with little runoff and minimal evapotranspiration.

The Kissimmee Prairie Ecosystem is located in Okeechobee County, east of C-38. It has a total area of about 46,000 acres, of which 7,000 acres lie within the boundary of the Kissimmee River Restoration Project. The remaining 39,000 acres form one of the most unique land mosaics in Florida. This ecosystem is mostly undisturbed and includes ten separate community types providing breeding habitat for numerous wildlife species. The dominant community type is dry prairie, and this tract is likely to be the largest and best example of its type in the world. This area has been acquired for conservation/preservation purposes.

Xeric, sand pine scrub communities most commonly occur along sand ridges and ancient dunes. The southernmost of these communities was once found on Marco Island in Collier County, but has since been lost to development. Sand pine scrub is most often associated with relic sand dunes formed when sea level was higher than it is today. These well-drained sandy soils are important areas of aquifer recharge for coastal communities. The sand pine scrub is the most endangered ecological community present within the Lower West Coast (LWC) Planning Area and is seriously threatened in the UEC Planning Area. It is rapidly being eliminated by conversion to other land uses. Xeric sand pine scrub communities, although not as diverse as pine flatwood communities, contain more endangered and threatened plants and animals than any other south Florida habitat. Most of the xeric sand pine scrub in the UEC Planning Area is associated with the 1-mile to 3-mile-wide ancient dune that lies along the eastern edge of the coastal ridge in Martin and St. Lucie counties.

Tropical hammocks are scattered throughout the southern counties. This diverse woody upland plant community occurs on elevated areas, often on Indian shell mounds along the coast, or on marl or limestone outcroppings inland. Tropical hammocks are not widespread in occurrence, and as a result, of conversion to other land uses, tropical hammocks are among the most endangered ecological communities in south Florida.

Estuaries

An estuary is defined as a partially enclosed body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the salty seawater. Estuaries and the lands surrounding them are places of transition from land to sea, and from fresh to salt water. Although influenced by the tides, estuaries are protected from the full force of ocean waves, winds and storms by the reefs, barrier islands or fingers of land, mud or sand that define an estuary's seaward boundary.

Functions and Values of Estuaries

Estuaries are important as nursery grounds for many recreationally and commercially important species, such as spiny lobster, penaeid shrimp, blue crab, oyster, spotted sea trout and stone crab. Estuaries serve as important habitat for a number of state and federally listed species, provide flood protection and shoreline protection during major storms and act as natural filters for water quality improvement.

Many freshwater wetland systems within the District provide base flows to extensive estuarine systems. Classic examples are Shark River Slough and the Taylor Slough/C-111 basins (Everglades National Park), which provides significant freshwater base flows to Whitewater Bay, the Ten Thousand Islands Area and Florida Bay. In Lee, Collier and Monroe counties, wetlands as far inland as the Okaloacoochee Slough in Hendry County contribute to the base flows entering some of these estuarine systems. Maintenance of these base flows is crucial to propagation of many fish species that are the basis of extensive commercial and recreational fishing industries. Due to the sensitive nature of these systems, estuaries are highly vulnerable to human development and drainage activities and present some unique sustainability challenges to protect these systems against habitat loss and alteration.

Coastal estuaries associated with south Florida watersheds include the southern reaches of the Indian River Lagoon, the St. Lucie River and Estuary, the Loxahatchee River and Estuary, Lake Worth Lagoon, Biscayne Bay, Florida Bay and the Florida Keys, the Caloosahatchee River and Estuary, Estero Bay and Charlotte Harbor. Ecosystem restoration and Surface Water Management and Improvement (SWIM) plans for the Indian River Lagoon, Southwest Florida Feasibility Study, Florida Keys/Florida Bay Feasibility Study, Biscayne Bay, Charlotte Harbor and the National Estuaries Program are discussed in a later section of this chapter.

One of the District's water management goals is to manage freshwater discharge to south Florida's estuaries in a way that preserves, protects and, where possible, restores essential estuarine resources. The District seeks to ensure that estuaries receive not only the right amount of water at the right time, but also clean, quality water.

Ecosystem Protection Programs

Key elements of the District's ecosystem protection program include activities, such as the establishment and implementation of Minimum Flows and Levels (MFLs) for priority water bodies (major lakes, rivers, estuaries and wetland systems located within the SFWMD); wetlands protection and regulation polices and the District's Land Acquisition Program.

Minimum Flows and Levels

The overall purpose of Chapter 373 is to ensure the sustainability of water resources of the state (Section 373.016, F.S.). To carry out this responsibility, Chapter 373 provides the District with several tools, with varying levels of resource protection standards. Minimum Flows and Levels (MFLs) play one part in this framework.

The purpose of establishing MFLs is to avoid diversions of water that would cause significant harm to the water resources or ecology of an area. The Florida Legislature has mandated that all water management districts establish MFLs for surface waters and aquifers within their jurisdiction. Section 373.042(1) F.S. defines the minimum flow as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." It further defines the minimum level as the "level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." The District was further directed to use the best available information in establishing a minimum flow or a minimum level.

The scope and context of MFLs protection rests with the definition of significant harm. The following discussion provides some context to the MFLs statute, including the significant harm standard, in relation to other water resource protection statutes.

Pursuant to Parts II and IV of Chapter 373, surface water management and consumptive use permitting regulatory programs must prevent harm to the water resource. Whereas, water shortage statutes dictate that permitted water supplies must be restricted from use to prevent serious harm to the water resources. Other protection tools include reservation of water for fish and wildlife or health and safety [Section 373.223(3)] and aquifer zoning to prevent undesirable uses of the groundwater (Section 373.036). By contrast, MFLs are set at the point at which significant harm to the water resources or ecology would occur. The levels of harm cited above, harm, significant harm and serious harm, are relative resource protection terms, each playing a role in the ultimate goal of achieving a sustainable water resource.

Although undefined by statute, the implication is that the minimum flow or level criteria should consider impacts that are more severe than those addressed by the consumptive use permitting harm standard, but less severe than the impacts addressed by the serious harm water shortage standard.

Minimum Flows and Levels (MFLs) were developed in 2001 for the Caloosahatchee River, the Lower West Coast Aquifers, the Everglades (Holey Land and Rotenberger Wildlife Management Areas, Water Conservation Areas 1, 2 and 3 and Everglades National Park), Lake Okeechobee and the northern portion of the Biscayne Aquifer and the St. Lucie River and Estuary. In 2003, MFLs were developed for the Northwest Fork of Loxahatchee River. The District's MFL Priority List identifies 23 more water bodies that are scheduled to have MFLs developed during the next five years. Five of these—Florida Bay, Lake Istokpoga, Biscayne Bay, Lower West Coast Water Table Aquifer and the southern portion of the Biscayne Aquifer—are scheduled for completion by 2005.

Wetland Protection Policies

The District protects and enhances natural resources through its restoration activities and with integrating planning, regulation and land acquisition programs. Regulatory programs include rules to protect, enhance, mitigate and monitor wetlands and water resources; and develop and enforce rules that address water quantity and quality.

The District prevents adverse impacts to wetlands from groundwater withdrawals by implementing numerous state laws through the consumptive use permitting process, which limits drawdown beneath wetlands. The permitting process is based on interpretation and implementation of the law to ensure that wetlands are protected. The obligation to leave enough water in natural areas to maintain their functions and protect fish and wildlife is central to water supply planning in the regional planning areas.

The State Comprehensive Plan states:

> Paragraph 187.201(7)(a), F.S. *Goal.*--Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present level of surface and ground water quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards.
>
> Paragraph 187.201(7)(b)14, F.S. *Policies.*-- Reserve from use that water necessary to support essential nonwithdrawal demands, including navigation, recreation, and the protection of fish and wildlife.

The extent, to which wetland preservation conflicts with water supply development, depends greatly on the approach of that development. For example, options that increase water storage relieve the conflict between wetlands and human development, as does appropriate location and design of wellfields or the use of surface water. The challenge is to accept wetland protection as a constraint and to protect wetlands from harm; and, develop the most reliable and cost-effective water supply strategy.

Wetland Impacts Due to Consumptive Use

Wetlands impacts are reviewed through the Consumptive Use Permitting (CUP) Program. Wetlands are identified during the review process and an analysis of potential impacts on wetland systems is performed. The applicant, as well as District staff, often models the potential drawdown effect on wetlands by wellfields or dewatering operations to determine the extent of potential impact. Adverse impacts to wetlands through dewatering or wellfield drawdowns cannot be permitted. If an adverse impact is identified, the application must be modified to eliminate the adverse impact or staff will recommend a reduced allocation. Development has begun on a rule that would allow limited drawdown under wetlands.

Environmental Resource Permitting

The *Florida Environmental Reorganization Act of 1993* consolidated dredge and fill permitting and surface water management permitting activities into one program implemented through Chapter 373, F.S. The Environmental Resource Permits (ERP) Program deals with the construction of surface water management systems and dredge and fill activities. Surface water management systems are required for all forms of development: agricultural, commercial and residential. Developed sites, containing more impervious surfaces or altered topography, must provide a way to direct storm water to water management areas for water quality treatment and flood attenuation.

During the ERP application review process, wetlands are evaluated both on and adjacent to the project site. If wetland impacts are proposed in an ERP application, an analysis is conducted to determine if the impacts can be eliminated or reduced. If the proposed wetland impacts are determined to be allowable, an applicant will need to provide compensation for the loss of the wetland functions. Generally, this is accomplished through mitigation. Mitigation consists of the restoration or enhancement of existing wetlands, the creation of new wetland habitat or a combination of these methods. If the applicant proposes to preserve the wetlands on the project site, an analysis is conducted to determine what effects the development will have on the wetlands. An applicant must ensure that an upland buffer exists, adequate amounts of water will be available, wetlands will not be inundated for prolonged periods and a conservation easement is provided to ensure long-term protection.

Florida Department of Environmental Protection (FDEP) Dredge and Fill Delegation

Changes in the regulatory program were implemented under the terms of an operating agreement, approved in 1992, between the SFWMD and FDEP. In November 1992, the SFWMD began reviewing certain dredge and fill activities proposed in FDEP jurisdictional wetlands. The operating agreement specified the type of projects in which the SFWMD could authorize dredging or filling activities in FDEP jurisdictional wetlands. The delegation agreement was the first step towards achieving a one-stop permitting program in Florida.

Environmental Compliance Program

In 1989, the District completed an internal study assessing the ability of its regulatory program to manage and protect wetland resources. An independent company analyzed the program. As a result of those studies, a major initiative to develop a post-permit compliance program was undertaken in 1990, and the District has staffed a wetland mitigation compliance work unit since 1992. This unit reviews submitted monitoring reports and verifies success criteria on-site. Mitigation sites are monitored for five years and thereafter site inspections are completed annually.

Land Resources Programs

Save Our Rivers

The Save Our Rivers (SOR) Program began in 1981 with the legislative enactment of the Water Management Lands Trust Fund, Chapter 373.59, F.S., which enabled the five water management districts to buy lands needed for water management, water supply and the conservation and protection of water resources, and to make them available for appropriate public use. Since that time, South Florida Water Management District has purchased 361,000 acres of environmentally sensitive land (not including 800,000 acres in the three water conservation areas). Water resource projects, or those lands associated with the Comprehensive Everglades Restoration Project, consisting largely of impacted agricultural lands, have added another 153,000 acres.

Land Stewardship Program

The Land Stewardship Program is responsible for the planning and management of SOR lands and the implementation and administration of mitigation banks and regional offsite mitigation areas. A major thrust of the Land Stewardship Program is to protect and restore the flowways, watersheds and wetlands, all of which are critical to the water resources of the District. The program has direct management responsibility for 172,000 acres in 13 projects, including two mitigation banks and several regional mitigation areas. For the 190,000 acres of non-District-managed lands, agreements or leases have been entered into with other agencies or local governments. The major goals of the program are to restore the lands to their natural state and condition, manage them in an environmentally acceptable manner, and to provide public recreational opportunities that are compatible with natural resources protection. Program objectives include:

- Complete/update management plans for all SOR projects
- Restore native communities
- Implement and administer mitigation banking projects
- Control invasive exotics
- Restore natural fire regime (prescribed burning)
- Public use and education on SOR lands

The program is implemented by SFWMD staff based in five service centers and at headquarters in West Palm Beach.

Public Use & Environmental Education on SOR Lands

The District encourages use of its lands for appropriate outdoor recreational activities. All SOR lands are available for public use, except in rare instances where there is no legal public access or where lease restrictions prohibit public access. The vast majority of SOR lands are managed as semi-wilderness areas, with very limited vehicular access other than off-road parking. Opportunities include hiking, primitive camping, canoeing, fishing and horseback riding, with volunteers from various user groups maintaining the trails and wilderness campsites. Cooperative agreements with the Florida Fish and Wildlife Conservation Commission enable high quality, low impact hunting on nearly 180,000 acres. Acquisition and management partners from several counties have constructed environmental education centers, boardwalks and interpretive trails, all at no cost to the District, that are used by thousands of school children and adults annually.

Wetland Mitigation Banking

Under Chapter 373, (F.S.), the District is authorized to participate in and encourage the development of private and public mitigation banks and regional offsite mitigation areas. Furthermore, the state's mitigation banking rule, Chapter 62-342, encouraged each water management district to establish two mitigation banks. The use of mitigation and mitigation banking offers opportunities to supplement funding of the District's land acquisition, restoration and management programs. The District's mitigation bank sites include the Loxahatchee Mitigation Bank in Palm Beach County and the Corkscrew Regional Mitigation Bank in Lee County. The District is developing each bank in a public-private contractual agreement. Private bankers obtain permits, restore the land, reimburse the District for its land acquisition and staff costs, and then generate a revenue stream for future projects. As of late 2002, the Loxahatchee Mitigation Bank has completed the construction phase and the Corkscrew Regional Mitigation Bank is in the final permitting phase. In 2000, the District Governing Board approved the use of five projects for regional mitigation activities. Three are currently being used as expenditure sites for mitigation funding, including Pennsuco in Miami-Dade County, Corkscrew Regional Ecosystem Watershed (CREW) in Lee and Collier counties and Shingle Creek in Orange and Osceola counties.

Control of Exotics

Control of exotic plant infestations upon public lands is a key task of the Land Stewardship Program. Exotic control consists of the proper application of various environmentally acceptable chemical herbicides combined with mechanical techniques performed by staff or private contractors. Cooperators who manage District lands under contract or lease are strongly encouraged to apply a similarly aggressive approach to exotic plant control. Exotic control is consistently the single largest item in the Land Stewardship Program annual budget.

Prescribed Burning

Restoration of the natural fire regime (prescribed burning) to lands managed by the District is another function of the Land Stewardship Program. Periodic fire is a natural element of native Florida ecosystems. The District uses prescribed burning to reduce hazardous buildup of vegetative fuel loads, enhance wildlife habitat and encourage restoration of native plant communities. The Fire Management Program is based on ecological research and proven safety standards, requiring trained and experienced staff familiar with the diverse and unique fire management needs of the Florida landscape.

Florida Forever Program

The Florida Legislature established the Florida Forever Program in 1999. This program is intended to accomplish environmental restoration, enhance public access and recreational enjoyment, promote long-term management goals and facilitate water resource development.

All lands acquired with Florida Forever funding are to be used for "multiple-use" purposes. "Multiple-use" includes outdoor recreational activities, water resource development projects and sustainable forestry management. Water resource or water supply projects may be allowed only if the following specified conditions are met: minimum flows and levels (MFLs) have been established for those waters, which may incur significant harm to water resources, the project complies with permitting requirements and the project is consistent with the regional water supply plan.

Cooperative Management Agreements

In addition to agreements with the Florida Fish and Wildlife Conservation Commission (FWC), the District has entered into cooperative agreements with other state agencies, local governments and the private sector for assistance in the management of certain SOR lands. In most cases, the SFWMD has a Memorandum of Agreement (MOA) and an annual work plan that detail services and compensation. The cooperators provide many services for which the SFWMD does not pay, including managerial, planning and administrative support from the organization's headquarters staff and specialized services, such as law enforcement and management of public hunting.

Ecosystem Monitoring and Assessment Programs

The District maintains an extensive monitoring network throughout the District to evaluate and assess hydrologic and water conditions within wetlands, lakes, rivers and estuaries. Hydrologic and meteorological data are obtained through an electronic data collection network covering 1,426 water control structures and water level recording stations. The network also includes 347 rainfall collection sites. These data are used on a daily basis to help water managers make water management decisions that affect south Florida's environment. The District currently maintains 30 water quality programs designed to meet the permit requirements and information needs of specific projects, restoration programs and the public. Approximately 2,200 water quality monitoring sites (both surface and groundwater) exist throughout the District. Approximately 51,000 water quality samples are collected and analyzed from these sites annually. The overall mission of the District's Environmental Monitoring & Assessment Department is to provide scientific and legally defensible environmental data and assessments in a timely, accessible manner, utilizing optimal long-term monitoring networks.

ENVIRONMENTAL WATER NEEDS

Water Needs of Coastal Resources

Natural systems on costal ridges and barrier islands depend primarily on groundwater levels and rainfall as their primary sources of fresh water. Therefore, these communities can be affected by lowering of the groundwater table due to withdrawals for landscape irrigation and consumptive use.

Maintenance of appropriate freshwater inflows is essential for a healthy estuarine system. Flow regimes are typically defined in terms of total mean monthly inflows and a suitable range of acceptable minimum and maximum flow rates. Excessive changes in freshwater inflows to the estuary result in imbalances beyond the tolerances of estuarine organisms. The retention of water within upland basins for water supply purposes can reduce inflows into the estuary and promote excessive salinities. Conversely, the inflow of large quantities of water into the estuary due to flood control activities can significantly reduce salinities and introduce stormwater contaminants. In addition to the immediate impacts associated with dramatic changes in freshwater inflows, long-term cumulative changes in water quality constituents or water clarity may also adversely affect the estuarine community.

Estuarine flora and fauna are well adapted to natural seasonal changes in salinity. The temporary storage and concurrent decrease in velocity of floodwaters within upstream wetlands aids in controlling the timing, duration and quantity of freshwater flows into the estuary. Upstream wetlands and their associated groundwater systems serve as freshwater reservoirs for the maintenance of base flow discharges into the estuaries, providing favorable salinities for estuarine biota. During the wet season, upstream wetlands provide pulses of organic detritus, which are exported down stream to the brackish water zone. These materials are an important link in the estuarine food chain.

The estuarine environment is sensitive to freshwater releases and disruption of the volume, distribution, circulation, temporal patterns of freshwater discharges could place severe stress on the entire ecosystem. Such salinity patterns affect productivity, population distribution, community composition, predator-prey interactions and food web structure in the inshore marine habitat. In many ways, salinity is a master ecological variable that controls important aspects of community structure and food web organization in coastal systems. Other aspects of water quality, such as turbidity, dissolved oxygen content, nutrient loads and toxins, also affect functions of these areas.

Water Needs of the Inland Environment

Both the needs and functions of natural systems must be considered as part of the overall water supply planning process. Wetland and upland communities play an integral role in maintaining regional water supplies by allowing for natural recharge of the aquifers.

Wetland Water Supply Needs

Maintaining appropriate wetland hydrology (water levels and hydroperiod) is the single most critical factor in maintaining a viable wetland ecosystem. Rainfall, along with associated groundwater and surface water inflows, is the primary source of water for the majority of wetlands in the regional planning areas. The natural variation in annual rainfall makes it difficult to determine what the typical water level or hydroperiod should be for a specific wetland system. Because wetlands exist along a continuous gradient, changes in the hydrologic regime may result in a change in the position of plant and animal communities along the gradient. The effects of hydrologic change are both complex and subtle, influenced by and reflecting regional processes and impacts, as well as local ones.

James Gosselink stated in a 1994 study on wetland protection from aquifer drawdown that a critical issue to be considered in the water supply planning process is how wellfield induced groundwater drawdowns affect wetlands. An adverse environmental impact can be defined as: 1) a change in surface or shallow groundwater hydrology that leads to a measurable change in the location of the boundary of a wetland; or 2) a measurable change in one or more structural components of a wetland as compared to control or reference wetlands, or to the impacted wetland before the change occurred (Gosselink *et al*., 1994). Lowered groundwater tables in areas adjacent to wetland communities have been shown to decrease wetland surface water depths and shorten the hydroperiod (length of inundation).

Aquifer drawdown and its subsequent effect on wetlands are best measured using three parameters; severity (the depth of the drawdown), duration (the length of time) and frequency (how often that drawdown occurs). Shallow, low gradient wetlands, may be eliminated by lowered water levels. Decreased wetland size reduces the available wildlife habitat and the area of vegetation capable of nutrient assimilation. Lowered water levels and reduced hydroperiod: 1) induce a shift in community structure towards species characteristic of drier conditions; 2) reduce rates of primary and secondary aquatic production; 3) increase the destructiveness of fire; 4) cause the subsidence of organic soils; and 5) allow for exotic plant invasion.

Some wetland types contain water depths of 3 feet or more and are inundated year round, while other community types are characterized by saturated soils or water depths of less than a few inches that inundate the land for relatively short periods during the wet season. Wetland flora and fauna adapted to deep water and long periods of inundation are generally not well adapted to shallow water or a shortened hydroperiod. Complete drainage of a wetland severely alters wetland community organization and species composition. Partial drainage of wetlands can be caused by groundwater withdrawals in adjacent upland areas. These withdrawals effectively lower underlying water tables and "drain" wetlands. Drainage facilities, such as canals and retention reservoirs constructed near wetlands, have a history of draining and reducing hydroperiods of south Florida wetlands. A major concern of reduced water depths and hydroperiod within wetlands is the invasion of exotic plants, such as melaleuca and Brazilian pepper.

Rainfall, along with associated groundwater or surface water inflows, is the primary source of water for the majority of wetlands in the regional planning areas. Rainfall in south Florida is highly variable. Although the region has a distinct wet and dry season, the timing and amount of rain falling upon a particular wetland varies widely from year to year. As a result, wetland hydroperiod also varies annually. Hydroperiod information collected from a wetland during a series of wet years may vary considerably from data collected during a dry year. This wide variation in annual rainfall makes it difficult to determine what the appropriate water level or hydroperiod should be for a specific wetland ecosystem. Determining appropriate water level or hydroperiod conditions for a wetland often requires a data collection effort that spans a sufficient period of record.

The District's Wetland Drawdown Study has gathered sufficient data to calibrate integrated surface and groundwater models capable of simulating wetland hydroperiod. Although the data requirements tend to limit these modeling efforts to a local scale, they can be used to predict the effect of groundwater stresses on wetland hydroperiod, and aid in the evaluation of criteria for wetland protection. This knowledge could be utilized in determining appropriate flows from wetlands through tributaries to estuaries.

Upland Water Needs

Seasonal variations play an important role in determining the type of upland vegetation that will develop. It is generally thought that plant communities located in uplands are better able to adapt to dry season hydroperiod fluctuation as compared to plants in wetlands. The water supply needs of upland plant communities are not well known. It is assumed that the upper 6 to 10 feet of the Surficial Aquifer is utilized by forest and herbaceous plant vegetation. These plant associations are characterized by low, flat topography and poorly drained, acidic, sandy soils. In the past, this ecosystem was characterized by open pine woodlands and supported frequent fires. Fire frequency, soil moisture and hydrology play important roles in maintaining plant community structure and function. These three factors are considered important as determinants of the direction of plant community succession. Fire most strongly influences the structure and composition of upland plant communities.

Fire, under natural conditions, maintains flatwoods as a stable and essentially non-successional plant association. However, when the natural frequency of fire is altered by drainage improvements, construction of roads or other fire barriers, flatwoods can succeed to several other plant community types. The nature of this succession depends on soil characteristics, hydrology, available seed sources or other local conditions. The hydrology of upland plant communities varies with elevation and topography. Seasonal variations, as well as local withdrawals from groundwater play an important role in determining the type of upland vegetation that will develop.

Water Needs of Native Vegetation

The location of south Florida between temperate and subtropical latitudes, the proximity to the West Indies, the expansive wetland system of the greater Everglades and the low levels of nutrient inputs, under which the Everglades evolved, all combine to create a unique and species-rich flora and vegetation mosaic. Today the majority of south Florida's native vegetation has been substantially altered by drainage and development, resulting in hydrology changes, nutrient inputs and the spread of exotics, resulting directly or indirectly from a century of water management (USACE, 1999).

Riparian plant communities of the Kissimmee River and its floodplain are recovering from channelization and drainage. The macrophyte communities of the diminished littoral zone of Lake Okeechobee are now contained within the Hoover Dike. They remain essential for the ecological health of the lake, but are stressed by extreme high and low lake levels and by the spread of exotics.

Below Lake Okeechobee, all of the pond apple swamp forest and most of the sawgrass plain of the northern Everglades have been converted to the EAA. In addition, the band of cypress forest along the eastern fringe of the Everglades was largely converted to agriculture after the eastern levee of the WCAs cut off this community from the remaining Everglades. The mosaic of macrophytes and tree islands within the WCAs and Everglades National Park is altered by changes in hydrology, exotic plant invasion and nutrient inputs.

The problems of the Everglades extend to the mangrove estuary and coastal basins of Florida Bay, where the forest mosaics and submerged aquatic vegetation show the effects of diminished freshwater heads and flows upstream that are exacerbated by a rise in sea level. The upland pine and hardwood hammock communities of the Atlantic coastal ridge were historically interspersed with wet prairies and cypress domes and dissected by "finger glades" watercourses that flowed from the Everglades to the coast. These remain only in small and isolated patches that have been protected from urban development.

More detailed documentation of existing vegetation focuses on wetland systems that have been most seriously degraded and that will receive the most benefits from the implementation of the components recommended in the *Central and Southern Florida Project Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Statement* (Restudy) (USACE and SFWMD, 1999). Those systems include the Everglades peatland; the Everglades marl prairie and rocky glades and the mangrove estuaries and coastal basins of Florida Bay. Other natural systems in south Florida already have restoration plans and have had lesser impacts from man. These systems include the Kissimmee River, where restoration is already in progress; Lake Okeechobee, for which a revised regulation schedule is planned to protect littoral, macrophyte communities; and the Big Cypress National Preserve where vegetation impacts and fixes are relatively minor compared to the Everglades. The Atlantic coastal ridge pinelands and hardwood hammocks, and the hammock and dune communities along the beaches are unique subtropical ecosystems that have very little protection and are rapidly disappearing.

Water Needs of Fish and Wildlife

The life cycles, community structures and population densities of the fauna of south Florida are intricately linked to regional hydrology. The status of fish and wildlife has been strongly influenced by the cumulative effects of drainage activities early this century, the C&SF Project and ensuing agricultural and urban development. The major emphasis in this section is on those faunal groups that appear to have declined due to hydrologic changes caused by the C&SF Project. The major linkages between hydrologic alterations and fauna that are emphasized here include the decline of aquatic food webs and populations, higher level consumers that depend upon them, shifts in habitats to those less favorable to faunal communities and the reduction in the spatial extent of the Everglades wetland system.

A critical link in the aquatic food webs, and one that appears to have been impacted by hydrologic alterations, is the intermediate trophic level of the small aquatic fauna. The small marsh fishes, macro-invertebrates, amphibians and reptiles, which form the link between the algal and detritus food web bases of the Everglades and the larger fishes, alligators and wading birds that feed upon them, are diminished due to loss of habitat and changes in hydrology.

Included in the freshwater aquatic community of south Florida are the larger sport species, such as the largemouth bass (*Micropterus salmoides*), sunfishes and black crappie (*Lepomis nigromaculatus*). Lake Okeechobee is renowned for the trophy bass from its littoral zone and for an abundant black crappie fishery. Largemouth bass also naturally inhabit the deep-water sloughs and wet prairies of the Everglades.

The American alligator (*Alligator mississippiensis*) is a keystone species in the Everglades. Holes that are created by alligators form ponds where aquatic fauna survive droughts. Mounds of sediment that are excavated from the holes create higher-elevation habitat for willow and other swamp forest trees. In addition to modifying topography, the American alligator is the top predator in the Everglades and feeds on every level of the food chain, from small fishes to wading birds, at various stages in its life.

The most conspicuous indicators of ecosystem health in the Everglades are the plummeting populations of wading birds. At present, nesting birds have declined to only ten percent of their historical number and they continue to decline. The food bases for these species are mostly contained in the freshwater marsh fish assemblage of the Everglades and the low salinity mangrove fish assemblage of the estuarine transition zone.

Due to diminished freshwater heads and flows upstream, habitats for the American crocodile (*Crocodylus acutus*) and migratory waterfowl, and nursery grounds of estuarine and marine sport fishes and pink shrimp (*Penaeus duorarum*) were also degraded.

In contrast, the deer population has benefited from lower water levels. More white-tailed deer (*Odocoileus virginianus*) presently live in the Everglades than occurred under predrainage conditions. However, during high water periods, large-scale mortality can occur when the deer are stranded on over-browsed tree islands.

REGIONAL RESTORATION PROJECTS

Comprehensive Everglades Restoration Plan

The Comprehensive Everglades Restoration Plan (CERP) provides a framework and guide to restore, protect and preserve the water resources of central and southern Florida, including the Everglades. It covers 16 counties over an 18,000-square-mile area, and centers on an update of the Central & Southern Florida (C&SF) Project. The C&SF Project includes 1,000 miles of canals, 720 miles of levees and several hundred water control structures. The C&SF Project provides water supply, flood protection, water management and other benefits to south Florida. For close to 50 years, the C&SF Project has performed its authorized functions well. However, the project has had unintended adverse effects on the unique and diverse environment that constitutes south Florida ecosystems, including the Everglades and Florida Bay.

The *Water Resources Development Acts of 1992* and *1996* provided the U.S. Army Corps of Engineers (USACE) with the authority to reevaluate the performance and impacts of the C&SF Project and to recommend improvements and or modifications to the project in order to restore the south Florida ecosystem and to provide for other water resource needs. The resulting Comprehensive Plan was designed to capture, store and redistribute fresh water previously lost to tide and to regulate the quality, quantity, timing and distribution of water flows.

The Comprehensive Plan was approved in the *Water Resources Development Act of 2000*. Described as the world's largest ecosystem restoration effort, CERP includes more than 60 components, will take more than 30 years to construct and will cost an estimated $8.4 billion. The major Plan components are:

1. Surface Water Storage Reservoirs.
2. Water Preserve Areas.
3. Management of Lake Okeechobee as an Ecological Resource.
4. Improved Water Deliveries to the Estuaries.
5. Underground Water Storage.
6. Treatment Wetlands.

7. Improved Water Deliveries to the Everglades.
8. Removal of Barriers to Sheet Flow.
9. Storage of Water in Existing Quarries.
10. Reuse of Wastewater.
11. Pilot Projects.
12. Improved Water Conservation.
13. Additional Feasibility Studies.

Comprehensive Integrated Water Quality Feasibility Study

The Comprehensive Integrated Water Quality (CIWQ) Feasibility Study is a study cosponsored by the USACE and the Florida Department of Environmental Protection (FDEP). The study is the result of a recommendation of the Central and Southern Florida Project Comprehensive Review Study (Restudy). The Restudy recognized the need for a comprehensive water quality plan that would integrate the CERP projects and other federal, state and local government programs.

The study area for the project is the SFWMD boundary plus the study area for the Indian River Lagoon – North Feasibility Study (IRLN). The IRLN project is within the St. Johns River Water Management District (SJRWMD) boundary.

The CERP includes a number of construction features, such as stormwater treatment areas (STAs), specifically designed to improve water quality conditions for the purpose of south Florida ecosystem restoration. Further, the CIWQ Plan includes other construction features, such as water storage reservoirs that could be designed to maximize water quality benefits to downstream water bodies. Optimizing the design and operation of construction features of the recommended plan to achieve water quality restoration targets is essential for achieving overall ecosystem restoration goals for south Florida.

Degradation of water quality throughout the study area is extensive, particularly in agricultural and urban coastal areas. The FDEP listed approximately 160 use-impaired water bodies in south Florida in its 1998 Section 303(d) list. There are several ongoing water quality restoration programs in the study area [e.g. National Pollutant Discharge Elimination System (NPDES) point and non-point source regulatory programs, total maximum daily loads (TMDLs) development and remediation programs, Surface Water Improvement and Management (SWIM) planning efforts]. The overall goal of the CIWQ Plan is to develop a comprehensive plan for linking these water quality improvement programs and water quality restoration targets with the ongoing CERP ecosystem restoration effort. It is also recognized that achieving all of the water quality goals for ecosystem restoration in all use-impaired water bodies within the study area will depend on actions outside the scope of the CERP.

The SFWMD, FDEP, U.S. Environmental Protection Agency (USEPA) and other agencies have developed or are developing water quality improvement programs for several of the impaired water bodies within the study area. The most notable example is the *Everglades Forever Act*, which focuses on achieving adequate water quality in the Everglades. Other examples include the SWIM planning efforts for the Indian River Lagoon, Lake Okeechobee and Biscayne Bay and the Florida Keys National Marine Sanctuary Water Quality Protection Program.

The FDEP has agreed to participate in the Project Management Plan (PMP) phase of the feasibility study as the local sponsor. The USACE and the FDEP will work together with other federal, state and local agencies to identify problems, opportunities and potential solutions for ecosystem restoration as they relate to water quality issues.

Indian River Lagoon South Project

The SFWMD, in cooperation with the USACE, conducted the Indian River Lagoon Feasibility Study to address water quality issues in St. Lucie Estuary and Indian River Lagoon. The purpose of feasibility study was to evaluate methods to improve surface water management in the C-23, C-24, C-25 and C-44 basins by providing increased storage and reducing the need for periodic high-volume freshwater discharges to the estuarine system.

The Final Indian River Lagoon – South Feasibility Study recommended a plan in Martin, St. Lucie and Okeechobee counties that will deliver the right amount of water, of the right quality, to the right places, and at the right time. The Final Indian River Lagoon – South Project Implementation Report (PIR) recommends a plan in Martin, St. Lucie, and Okeechobee counties that will improve water quality within the SLE and the IRL by reducing the damaging effects of watershed runoff; reducing high peak freshwater discharges to control salinity levels; and reducing nutrient loads, pesticides and other pollutants. The project will also provide water supply for agriculture to offset reliance on the Floridian Aquifer. The Ten Mile Creek Critical Restoration Project initiated in 2003, will also address regional storage and freshwater flows from the watershed.

The *Final Indian River Lagoon – South Project Implementation Report Public Notic*e was signed by the USACE in Atlanta in March 2004. The Indian River Lagoon PIR will be submitted to the USACE Headquarters in Washington, D.C. for final review. Approvals are being sought to incorporate the Indian River Lagoon – South Project in the WRDA 2004. Construction could start as early as 2006, and be complete within six years, at an estimated cost of $1.21 billion.

The recommended plan in the Indian River Lagoon – South PIR provides over 135,000 acre-feet of storage via four reservoirs covering 12,610 acres. The reservoirs, with their associated stormwater treatment areas, are expected to increase surface water availability, which should reduce agricultural demand on the Floridan Aquifer in the area.

In addition, four stormwater treatment areas are proposed to reduce phosphorus and nitrogen. These treatment areas encompass 8,731 acres, and will provide 35,000 acre-feet of storage. Additionally, 92,130 acres of natural storage and treatment areas will provide over 30,000 acre-feet of storage. The project is expected to increase water availability by 26,300 acre-feet per year (23.48 MGD), which will result in a decrease in Floridan Aquifer usage for agriculture.

The Indian River Lagoon – South Project also incorporates the removal of 5,500 cubic yards of muck and the creation of 90 acres of artificial habitat. Integrated as a component of the plan, the restoration of the North Fork floodplain includes reconnection of historic oxbows and acquisition of over 3,000 acres of floodplain.

A separate feasibility study effort is ongoing to investigate the northern portions of the Indian River Lagoon. That feasibility study will investigate water resource problems in Brevard, Volusia and Indian River counties associated with the existing C&SF Project system. A multiagency, interdisciplinary team has been formed to perform this study. The local sponsor is the St. Johns River Water Management District (SJRWMD).

Southwest Florida Feasibility Study

In the Restudy, which is now known as the CERP, it was recognized that, southwest Florida needs a comprehensive look at all the water issues it faces, not only those related to the Caloosahatchee River Basin and the C&SF Project. Other hydrologic watersheds in southwest Florida have not been studied in a comprehensive fashion. Thus, the Southwest Florida Feasibility Study (SWFFS) was one of the recommendations resulting from the Restudy and was needed to address all the watersheds of southwest Florida.

The SWFFS is being conducted by the USACE and the SFWMD. The study is investigating water resource problems and opportunities in all or parts of Lee, Collier, Hendry, Glades, Charlotte and Monroe counties. The purpose of the study is to determine the feasibility of making structural, nonstructural and operational modifications and improvements in the region in the interest of environmental quality, water supply and other purposes. The SWFFS will develop a comprehensive regional plan of action to address the health of aquatic and upland ecosystems; the quantity, quality, timing and distribution of water flows; agricultural, environmental and urban water supply; the sustainability of economic and natural resources; flood protection; fish and wildlife; biological diversity; and natural habitat.

The SWFFS area covers about 4,300 square miles including all of Lee County, most of Collier and Hendry counties and portions of Charlotte, Glades and Monroe counties. The project boundary corresponds to that of the *SFWMD Lower West Coast Water Supply Plan* (LWC Plan) Planning Area.

Florida Keys/Florida Bay Feasibility Study

Florida Bay is located at the southern tip of the Florida peninsula and covers about 850 square miles, including 700 square miles within Everglades National Park. The bay is relatively shallow, as average depths are less than 3 feet. The Florida mainland is located to the north and the Florida Keys lie to the southeast. Sheetflow across marl prairies of the southern Everglades and numerous creeks fed by Taylor Slough and the C-111 Canal provide fresh surface water inflows into the bay and groundwater recharge. Surface water from the Shark River Slough system flows into Whitewater Bay and may provide groundwater recharge for central and western Florida Bay.

At least 22 commercially and/or recreationally important aquatic species are known to use Florida Bay as a nursery ground. A guide boat industry in the Florida Keys operates within Florida Bay. Target species of this industry include snook, tarpon, permit, bonefish, spotted seatrout and mangrove snapper. The bay is also a nursery for young spiny lobsters and several species of snappers, grunts and sparids. Florida Bay and nearby coastal embayments are the principal nursery habitat for pink shrimp, which is the basis of a multimillion dollar fishery in the Tortugas. Pink shrimp are an important species commercially and form a prey base for higher trophic level organisms.

During the summer of 1987, approximately 100,000 acres of seagrass (primarily Thallassium testudinum) “died off” in western Florida Bay. Phytoplankton blooms and sponge die-offs followed this seagrass die off. Conditions within Florida Bay have continued to visibly decline since 1987, including losses of seagrass habitat; diminished water clarity; micro algal blooms of increasing intensity and duration; and population reductions in economically significant species, such as pink shrimp, sponges, lobster and recreational game fish. In addition to these problems, populations of wading birds forage fish and juveniles of game fish species have been reduced.

Recognizing Florida Bay’s ecological changes, the State of Florida and the federal government made a commitment to improve environmental management in order to restore the bay toward a more natural state. A collaborative interagency research program was initiated in 1994 in order to document the history of the bay, monitor status and trends, understand human impacts on the bay and provide a scientific basis for restoration. With partners from other state and federal agencies and the academic community, the District has initiated a comprehensive investigation of the bay and its upstream watershed to better understand the ecological consequences of alternative water management actions.

The CERP Florida Keys/Florida Bay Feasibility Study will ultimately provide a recommended plan of action to restore Florida Bay. As part of the feasibility study, data is being synthesized and assessed to better understand the effects of the C&SF Project on historic freshwater flow pathways, volumes of freshwater flow delivered to the bay and their effect on salinity and the biological response of estuarine organisms to these changes in salinity.

A key component of this project is the development of a hydrodynamic model for Florida Bay to simulate water movement patterns in the bay. Among other things, the model will support salinity predictions from varying temporal and spatial freshwater inflows, and in the future, will be linked with water quality and ecological models. For example, the model will accept output from surface and groundwater hydrologic models to predict the impacts that C&SF Project restoration alternatives will have on Florida Bay.

The District is in the process of developing a hydrodynamic model to simulate water movement and salinity patterns within Florida Bay. This model will be linked to a water quality model that can predict water clarity and potential algal bloom conditions. New models have also been developed by the USGS and the District to simulate upstream wetland hydrology to determine the role that freshwater inflows play in regulating salinity levels within Florida Bay. The District has also developed a seagrass model that can predict changing seagrass habitat in response to changes in salinity, temperature and nutrients. Ecological models are also under development for higher trophic level organisms present within the bay. These models will be used to assess how various restoration alternatives will affect Florida Bay. The models will also provide a foundation for the development of indicators for measuring the success of restoration efforts. In addition to these modeling efforts, a number of experiments are underway to determine how changes in salinity affect nutrient cycling within the bay. This nutrient research is coordinated with experiments on plants, including both mangrove trees and seagrasses.

Water Preserve Areas Feasibility Study

The Water Preserve Areas (WPAs) Feasibility Study investigated concepts to capture and store excess surface waters by backpumping water from the Lower East Coast urban areas that is normally discharged to tide via the C&SF Project canal system. The reconnaissance and feasibility phase of the C&SF Restudy demonstrated that the WPA concept is an integral part of the Everglades restoration plan.

The WPAs are located within Palm Beach, Broward and Miami-Dade counties east of the Water Conservation Areas and generally west of existing developed areas. Ecologic restoration of the Everglades will require a significant increase in water quantity. The WPAs provide a critical source for this new water by:

1. Reducing undesirable losses from the natural system through seepage.
2. Providing a means of backpumping stormwater runoff that was previous discharged to tide providing a new source of water.

Further, development continues to encroach on the remaining natural areas adjacent to the Everglades. These remaining wetland areas could serve a critical role in the restoration of the Everglades by increasing the overall spatial extent.

The WPA study also addresses other water-related needs, such as urban/agricultural water supply and water quality. The WPAs also provides a mechanism for increased aquifer recharge and surface water storage capacity to enhance regional water supplies for the Lower East Coast urban areas, reducing demands in an already degraded natural system.

Relationship with the Comprehensive Everglades Restoration Plan

The WPA Study was accomplished in conjunction with the CERP. The CERP reexamined the portions of the C&SF Project specific to Lake Okeechobee, Everglades Agricultural Area, Water Conservation Areas, Everglades National Park, Big Cypress National Preserve and Native American tribal lands. This was done to determine the feasibility of structural or operational modifications essential for restoration of the Everglades and Florida Bay ecosystems, to provide for other water-related needs to include water supply, water quality and flood damage prevention. The benefits associated with the WPAs include:

1. Reducing drainage of the Everglades and reestablishing natural hydropatterns within existing natural areas.
2. Providing for the creation of water storage systems (reservoirs), reducing demand on the natural system.
3. Providing short hydroperiod wetlands to increase spatial extent.
4. Providing a buffer between the Everglades and the increasingly urbanized Lower East Coast area.
5. Providing for improved water supply to the Lower East Coast.

Kissimmee River Restoration

Congress authorized the Kissimmee River Restoration Project in the *Water Resources Development Act of 1992*. The overall goal of this project is to restore over 40 square miles of river/floodplain ecosystem including 43 miles of meandering river channel and 27,000 acres of wetlands. The restoration project is a partnership between the South Florida Water Management District (SFWMD) and U.S. Army Corps of Engineers (USACE).

To achieve this goal, the physical form and the historic hydrology of the system must be recreated. The two primary components of the restoration project are the headwaters revitalization and the backfilling of the Lower Kissimmee Basin. The headwaters revitalization will modify the way water is released to the river in an effort to simulate historic flow conditions. The lower basin backfilling will fill the middle portion (22 miles) of the C-38 Canal and recreate the river's physical form and flow patterns.

As the restoration effort proceeds, a number of positive changes have been observed. Sandbars and sandy bottom are signs of improvement in the rivers' hydrology.

In formerly isolated sections of the river, oxbows are flowing again. Emergent and shoreline vegetation has reappeared and is thriving. Waterfowl are returning to the floodplain and water quality is improving. The project is reestablishing the physical form of the river with its historical water levels and flows, while ensuring existing flood protection.

Corkscrew Regional Ecosystem Watershed

The Corkscrew Regional Ecosystem Watershed (CREW) is a 60,000-acre project in Lee and Collier counties, consisting of Corkscrew Sanctuary, Corkscrew Swamp, Camp Keais Strand, Flint Pen Strand and Bird Rookery Swamp. Cypress forest, low pine flatwoods, hardwood hammocks, marshes, mixed swamps and ponds dominate the CREW lands. This system provides valuable habitat that supports at least 65 species of plants and 12 species of animals listed by the state as endangered or threatened.

The CREW Land & Water Trust was established in 1989 as a nonprofit organization to coordinate land acquisition, land management and public use of the 60,000-acre CREW. This watershed straddles Lee and Collier counties and provides aquifer recharge, natural flood protection, water purification, preservation of wildlife habitat and public recreation. Since 1990, the CREW Land & Water Trust has coordinated the purchase of nearly 26,000 acres.

The CREW Land & Water Trust coordinates the acquisition of land for conservation purposes, assists with land-management efforts (e.g., prescribed burns and exotic plant control), maintains hiking trails and camping sites and provides educational opportunities for students, scouts and the public.

The CREW Land & Water Trust was the first public/private partnership approach to an ecosystem-based acquisition project in southwest Florida The organization's Board of Trustees includes representatives of business, environmental groups, landowners and governmental agencies.

National Estuary Program

The Indian River Lagoon has been designated an estuary of national significance and is a component of the U.S. Environmental Protection Agency (USEPA) sponsored National Estuary Program (NEP). The IRL NEP Program was initiated in 1991 and was given five years to develop a Comprehensive Conservation Management Plan for the Indian River Lagoon. The plan was finalized May 1996. The Comprehensive Conservation and Management Plan incorporates the Indian River Lagoon SWIM Plan goals listed below, with the addition of a goal of identifying and developing long-term funding sources to implement the plan.

The Charlotte Harbor has also been designated an estuary of national significance and is a component of the USEPA sponsored NEP. The goals of the Charlotte Harbor National Estuary Program (CHNEP) include the following:

1. Improve the environmental integrity of the Charlotte Harbor study area.
2. Preserve, restore and enhance seagrass beds, coastal wetlands, barrier beaches and functionally related uplands.
3. Reduce point and non-point sources of pollution to attain desired uses of the estuary.
4. Provide the proper freshwater inflow to the estuary to ensure a balanced and productive ecosystem.
5. Develop and implement a strategy for public participation and education.
6. Develop and implement a formal Charlotte Harbor Management Plan with a specified structure and process for achieving goals for the estuary.

Guided by these goals, the CHNEP published a completed "Comprehensive Conservation and Management Plan (CCMP)" in April 2000. The CCMP details the actions needed to protect and improve the watershed, while balancing human need with natural systems.

Surface Water Improvement and Management

Two Surface Water Improvement and Management (SWIM) Plans have been adopted, which incorporate portions of the Upper East Coast (UEC) Planning Area: the Indian River Lagoon SWIM Plan and the Lake Okeechobee SWIM Plan. The overall goal of both plans is to protect and restore surface water bodies.

Indian River Lagoon SWIM Plan

The *Surface Water Improvement and Management Act of 1987* (Sections 373.453–373.459, F.S.) was established to aid in the restoration of priority water bodies throughout Florida. One such priority water body is the Indian River Lagoon, a 156-mile estuary stretching from New Smyrna Beach in Volusia County to Jupiter Inlet in Palm Beach County. The Indian River Lagoon is within the jurisdiction of two water management districts: SJRWMD and SFWMD. The Indian River Lagoon SWIM Plan boundary includes the St. Lucie Estuary and its contributing watershed. The Indian River Lagoon was designated in 1987 as a state priority water body for protection and restoration under the SWIM Act. Under provisions of the Act, the two water management districts that encompass the Indian River Lagoon were required to develop and implement a SWIM Plan to preserve, protect and restore the water body.

The Indian River Lagoon SWIM project is a joint program administered in cooperation with the St. John's River Water Management District. The program is designed to develop and execute a combination of research and practical implementation projects to protect or restore the environmental resources of the St. Lucie Estuary and Indian River Lagoon. The Indian River Lagoon SWIM Plan was completed in 1989 and updated in 1994 and 2002. The program has three goals:

1. Attain and maintain water and sediment of sufficient quality to support a healthy, seagrass-based estuarine ecosystem.
2. Attain and maintain a functioning seagrass ecosystem supporting endangered and threatened species, fisheries and wildlife.
3. Achieve heightened public awareness and coordinated interagency management.

The focus of this effort has been on the improvement of water quality entering the estuary and lagoon in terms of quantity, timing and distribution of fresh water, as well as the associated suspended materials and nutrients that are transported into the system. The Indian River Lagoon 2000–2005 SWIM Plan update provides key direction towards activities that will continue to improve surface water quality in the Indian River Lagoon watershed. The Plan update focuses on:

1. Describing the accomplishments since the adoption of the 1994 Indian River Lagoon SWIM Plan.
2. Establishing interim pollution load reduction goals (PLRGs) or concentration targets.
3. Describing the water quality trends and conditions in the Lagoon.
4. Establishing a specified list of implementation activities that need to occur over the next five years to continue surface water quality improvement.

The Indian River Lagoon 2000–2005 SWIM Plan update provides specific direction on goals, objectives, strategies and tasks that are necessary for restoration and water quality improvement. This specificity will assist the SFWMD in developing appropriate budgets for implementation activities that are clearly connected to the intent and purpose of the state's SWIM Program.

Lake Okeechobee SWIM Plan

The Lake Okeechobee SWIM Plan was enacted in 1989 and updated in August 1997 and again in 2002. The environmental element recognized that adverse impacts to the St. Lucie Estuary occur when regulatory releases are made through the St. Lucie Canal (C-44) for lake flood protection purposes. Large, unnatural freshwater releases from the lake through the C-44 to the St. Lucie Estuary alter the estuarine salinity gradient and transport significant quantities of sediment to the estuary. Biota within the

St. Lucie Estuary, Indian River Lagoon and near-shore reefs can be negatively affected by these high volume discharges.

The SWIM plans must be consistent with state water policy as outlined in Chapter 62-40, F.A.C., to provide guidance to the FDEP and the water management districts in the development and preparation of water management programs, rules and plans. Chapter 62-40.432 requires the water management districts to develop PLRGs for SWIM water bodies. The PLRG developed for Lake Okeechobee was a 40 percent reduction in phosphorus loading from the watershed, based on the conditions that existed from 1973 to 1979 (Federico *et al*., 1981), with an expected downstream benefit of maintaining the trophic state and the biological integrity of the lake. To assist in achieving this goal, the Lake Okeechobee Works of the District (WOD) Rule limited total phosphorus concentrations in runoff leaving land parcels. The total phosphorus concentration targets range from 0.18 to 1.2 milligrams per liter (mg/L).

The federal *Clean Water Act* [Title 33, Chapter 26, Subchapter III, Section 1313(d)], requires that each state develop total maximum daily loads (TMDLs) for each water-quality-limited segment reported. A TMDL reflects the total pollutant loading, from all contributing sources, that a water segment can receive without exceeding its capacity to assimilate the pollutant loads and still meet applicable water quality standards.

The phosphorus TMDL established for Lake Okeechobee is 140 metric tons (based on a five-year rolling average) to achieve an in-lake target phosphorus concentration of 40 parts per billion in the pelagic zone of the lake (FDEP, 2000). The restoration target was determined using computer models developed based on past research performed by the SFWMD using SWIM funds. This target will support a healthy lake system, restore the designated uses of Lake Okeechobee and allow the lake to meet applicable water quality standards. The 1997 SWIM Plan Update reported that phosphorus load reductions had occurred, but the 40 percent reduction in loads was not achieved. It recommended implementation of programs and projects to improve the lake and watershed water quality situation. Even with the update of these programs and projects, nutrient loads to Lake Okeechobee have not decreased significantly. Highest phosphorus inflows continue from the S-154 and S-191 basins where dairies are abundant and out-of-compliance sites are found. Phosphorus loadings to the lake are far in excess of the amount considered for a healthy Lake Okeechobee ecosystem and model data predict that it may take decades before in-lake phosphorus concentrations will respond to reduced external loads (SFWMD, 2003b).

However, several major accomplishments have been made in the restoration effort. A new regulation schedule for the lake was formally adopted by the USACE in July 2000. This schedule, the Water Supply and Environment (WSE) schedule uses climate forecasting to determine the volumes of water to release from the lake under flood control circumstances, and has the potential to provide environmental benefits for the lake and downstream systems, while not sacrificing water supply. More details regarding the WSE schedule can be found in **Chapter 9** of this document.

In January of 2003, the District's Governing Board accepted by resolution "Adaptive Protocols for Lake Okeechobee Operations." This document spells out in detail how lake managers can meet the intent of the WSE schedule by providing guidance to short-term operational decisions concerning volumes of water that can be released from the lake for flood control purposes, and procedures to be followed for addressing Lake Okeechobee and downstream water resource opportunities. The key feature of decisions made under the Adaptive Protocols is that they balance the missions of the SFWMD for water supply, flood protection and environmental protection, and comply with the regional water supply performance projected in the *Lower East Coast Regional Water Supply Plan* (LEC Plan), within the constraints of the approved WSE schedule.

Restoration efforts for Lake Okeechobee were advanced with the passing of the *Water Resources Development Act of 2000* (WRDA, 2000), which authorized the Comprehensive Everglades Restoration Plan (CERP). The CERP is expected to have substantial effects on the lake's hydropattern. It is projected to reduce the number of extreme high and low events and increase the occurrence of ecologically beneficial spring recession events. The act also authorizes projects that will reduce nutrient loads to the lake. These components include regional STAs, reclamation of isolated wetlands and regional water storage facilities, such as aquifer storage and recovery (ASR) wells and reservoirs.

The enactment of the *Lake Okeechobee Protection Act* (LOPA) (Section 373.4595, F.S.) in 2000 also advanced restoration efforts. This act provides an umbrella that captures many lake restoration efforts. It will significantly enhance mandates restoring and protecting the lake using a phased, watershed-based approach to reduce phosphorus loading to the lake and downstream receiving waters. Fulfilling this act will require a great deal of cooperation among government agencies and the public.

To facilitate the execution of the Lake Okeechobee Protection Plan, an interagency committee was formed with individuals from the FDEP, the Florida Department of Agriculture and Consumer Services (FDACS) and the SFWMD. The agencies are planning and implementing numerous management activities in the watershed to reduce phosphorus loading to the lake. These include the construction of surface water storage reservoirs and STAs; the restoration of isolated wetlands; the development and implementation of best management practices to control non-point sources of pollution; the continuation of research and monitoring to ensure the projects are designed and implemented to optimize success; the removal of phosphorus-rich sediment from tributaries to Lake Okeechobee; and the implementation of a sediment management feasibility study to determine whether or not it is feasible to reduce internal loading from the lake sediments. More information regarding the status of the LOPA activities can be found in the *Lake Okeechobee Protection Program Annual Report* to the Legislature (SFWMD, 2002c).

The 2002 update of the Lake Okeechobee SWIM Plan has set goals for the Lake Okeechobee SWIM Planning Area in the areas of water quality; environmental resources; flood protection and water supply; recreation, navigation and public involvement; and intergovernmental coordination. Objectives have been developed to accomplish these goals. Programs and projects are being developed and will be implemented to achieve these objectives.

Biscayne Bay SWIM Plan

The Biscayne Bay SWIM Plan was adopted in 1988, modified in 1989 and updated in 1995. The purpose of this plan is to evaluate the effectiveness of initial strategies, identify new issues and opportunities facing the bay and develop goals, objectives, strategies and projects to address these items. Solutions may involve continuing efforts, changing ongoing projects or initiating new actions. In addition, this document provides analysis of data collected since the original plan was approved. Elements of the plan include the following:

- Identification and discussion of priority issues in specific geographic areas of the bay, accompanied by high priority projects.
- Summarization of goals, objectives, strategies and projects to guide planning efforts.
- Updated descriptions of habitats and communities, freshwater flows, water quality data and issues.
- Summarization of the status of SWIM projects and the 24 recommendations in the 1988 Plan.

Issues

In many respects, Biscayne Bay is in fair to good condition. The establishment of Biscayne National Park in 1980 has protected most of the Bay from coastal development. Much of this improvement is associated with SWIM funded activities since 1988. There are several troubling trends, however, such as the presence of deformed fish, declining fisheries and increasing toxicants. Some problems have been stable and do not show a trend, but have never been dealt with effectively. This plan attempts to identify all the specific problems and recommend solutions for many of them. In general, these issues can be categorized broadly as follows:

- Degradation of water and sediment quality.
- Alteration of hydrology.
- Loss and alteration of natural systems.

Goals and Objectives

Management goals and objectives were developed to provide direction for effective and efficient management of Biscayne Bay. Projects are proposed that address the highest priority objectives and strategies. The approach to meeting these objectives follows a five-step process:

- Identify and assess the scope of problem.
- Develop control methods or plans.
- Implement (purchase, replant, construct, etc.).
- Monitor to determine success or failure.
- Redesign and reimplement (if necessary).

The goals are organized under three categories of issues:

- **Water Quality** – Maintain and improve water quality to protect and restore natural ecosystems and compatible human uses of Biscayne Bay.
- **Water Quantity** – Improve the quantity, distribution and timing of freshwater flows and circulation characteristics of Biscayne Bay as needed to protect and restore natural ecosystems.
- **Environmental Protection** – Protect environmental resources of Biscayne Bay and adjacent areas.

Sixteen objectives are associated with the goals. The underlying philosophy of the plan is to be comprehensive in nature. Some activities may be inappropriate for SWIM funding or best handled by alternative programs. Therefore, not every objective necessarily leads to a project. Associated with each objective are a series of strategies.

Priority Areas

Many areas of Biscayne Bay need attention and could benefit from research, investigation, enforcement or construction activities. Because SWIM resources are limited, priorities must be set. The plan emphasizes geographical areas where the most serious problems exist. The targeted areas, which include their respective hydrologic drainage basins or watersheds, include the following:

- Arch Creek.
- Miami River/ Canal (C-6).
- South Dade County (Canals 1, 100, 102,103, & 111, Levees 31N & 31E).

Charlotte Harbor SWIM Plan

In February 2003, the SFWMD Governing Board passed a resolution authorizing District staff to combine Pine Island Sound, Matlacha Pass, Ding Darling, Estero Bay and the Caloosahatchee Estuary to form one area called the Lower Charlotte Harbor. In addition, the governing board directed SFWMD staff to add the Lower Charlotte Harbor area to the District's SWIM priority water body list in Tier 1, and authorized staff to initiate development of a SWIM Plan. Work on that plan will start in Fiscal Year 2004 and will be completed in the Calendar Year 2005.

Drainage Districts

Chapter 298, Florida Statutes governs local water control districts. These 298 districts are empowered to develop and implement a plan for draining and reclaiming the lands, and control all water movement within their jurisdiction. The 298 districts have the authority to construct and maintain canals, divert flow of water, construct and connect works to canals or natural watercourses and construct pumping stations. They may also enter into contracts, adopt rules, collect fees and hold, control, acquire or condemn land and easements for the purpose of construction and maintenance.

The District's past practice has been to issue consumptive use permits to the 298 districts for surface water use, while not requiring individual permits for users within these districts. Some 298 districts, however, may not have received a consumptive use permit; in these cases, individual permits would be issued. The individual 298 districts must still meet all conditions for issuance of a permit. The permit indicates how water will be allocated, and should list the type and quantity of water use for each user.

CHAPTER 3
Water Conservation and Water Source Options

Water conservation and water source options are measures that either reduce water use or make additional water available from existing or alternative sources. When implemented together, conservation of water and development of water source options provide optimal use of water resources by reducing water use and extending water supplies.

Conservation, also known as demand management, is essentially permanent water use efficiencies at the point of demand. Water conservation does not apply to short-term water restrictions that are used during a water shortage. Examples of year-round methods to reduce water consumption include retrofitting homes, businesses and agricultural operations with devices that save water. Water conservation measures also include public education, local government ordinances, changes in rate structures to encourage conservation and mobile irrigation labs that help participants use water more efficiently. There are numerous ways to save water, and they are described in the Water Conservation section of this chapter.

Water source options, also referred to as supply management, are a means to diversify the water resources. Supply management involves increasing the availability of the resource at the point of supply. Water reclamation or reuse, after one or more uses is an example. Reclaimed water can be used for agricultural, golf course or urban landscape irrigation, cooling towers for electric plants or manufacturing. It may also involve treating lower quality or brackish water for use in the water treatment process, minimizing freshwater use.

Supply management is the purview of the water suppliers in selecting and implementing appropriate water sources based on particular characteristics of the utility, availability of sources for water supply and cost-effectiveness of treatment options. Improved technology can also change the feasibility of alternative water supply. In many cases, yesterday's costly alternative source is widely used today. For example, reverse osmosis (RO) was once far too expensive for utilities to consider unless they had no other alternative; today there are numerous RO plants throughout the District, treating water from brackish aquifers, such as the Floridan, to provide potable water to utility customers. There are numerous water source options discussed in the Water Source Options section later in this chapter.

ROLES IN REGIONAL WATER SUPPLY PLANS

Long-term conservation provides a basis for adjusting historic rates and patterns of water use in projecting future water demands in the regional water supply plans. Reducing future water demands before expanding water supplies is a prudent way to manage the water resources. Water source options are developed to meet the demands, while not harming the environment. The optimal solution is to employ both water conservation and water source options. This maximizes the use of existing supply sources, while reducing the need to develop new sources of water.

FLORIDA WATER CONSERVATION INITIATIVE

Following the 1999–2001 drought, the Department of Environmental Protection led a statewide Water Conservation Initiative with a simple goal: Florida must and can do more to use water more efficiently. The *Florida Water Conservation Initiative, April 2002*, describes the philosophy and methods of this challenge, which are similar to the philosophy that has been incorporated into the District's conservation strategy, and into its regional water supply planning process.

Within the existing legislative framework and in response to growing water demands, water supply challenges, and one of the worst droughts in state history, the SFWMD is increasing efforts in conservation. These efforts include funding to promote conservation practices (demand management) and development of alternative sources of water supply (supply management). Regional water supply plan updates as well as consumptive use permitting are being used to promote and require conservation of water resources. Supply and demand management can help extend water supplies and reduce water use.

Table 2 presents detailed information on the 51 recommendations from the *Florida Water Conservation Initiative*. It shows the tables of selected water conservation alternatives that six work groups summarized and ranked.

Table 2. Recommended Water Conservation Alternatives.

Water Conservation Alternative[a]	Priority	Respon-sible Entity	Total Score	Amount of Water Saved (1 to 5)[b]					Cost Effectiveness (1 to 3)[c]			Ease of Implementing (1 to 3)[d]		
AGRICULTURAL IRRIGATION														
AI-1: Cost-share and other incentives	High	F, S, W, I	10	💧	💧	💧	💧	💧	$	$	$	√	√	
AI-2: More mobile irrigation labs to achieve water conservation BMPs	High	F, S, W, I	10	💧	💧	💧	💧	💧	$	$	$	√	√	
AI-3: Increase rainfall harvesting and recycling of irrigation water	High	S, W	9	💧	💧	💧	💧	💧	$	$	$	√		
AI-4: Increase the reuse of reclaimed water	High	S, I	9	💧	💧	💧	💧	💧	$	$	$	√		
AI-5: Improve methods for measuring water use and estimating agricultural water needs	Med.	S, W, I	8	💧	💧	💧	💧		$	$		√	√	
AI-6: Conduct additional research to improve agricultural water use efficiency	Med.	S, W	8	💧	💧	💧	💧		$	$		√	√	
AI-7: Increase education and information dissemination	Med.	S, W	8	💧	💧	💧			$	$		√	√	√
AI-8: Amend WMD rules to create incentives for water conservation	Med.	S, W	8	💧	💧	💧	💧		$	$		√	√	

Legend
F=Federal agencies or Congress
S=State agencies or Congress
W=Water Management Districts
L=Local governments (city, county; includes public water supply utilities,both public/investor owned)
I=Industry businesses or organizations with standard-setting ability

[a] Bolded alternatives from FDEP Basic List of Water Conservation Alternatives to be Considered (FDEP, 2003).

[b] A score of 1 indicates the least water saved, 5 the most.

[c] A score of 1 indicates the least cost-effective, 3 the most cost-effective.

[d] A score of 1 indicates relatively difficult to implement, 3 relatively easy.

Table 2. Recommended Water Conservation Alternatives (Continued).

Water Conservation Alternative[a]	Priority	Respon-sible Entity	Total Score	Amount of Water Saved (1 to 5)[b]					Cost Effectiveness (1 to 3)[c]			Ease of Implementing (1 to 3)[d]		
LANDSCAPE IRRIGATION														
LI-1: Develop and adopt state irrigation design & installation standards and require inspection.	High	S, L	10	💧	💧	💧	💧	💧	$	$	$	√	√	
LI-2: Expand and coordinate educational/outreach programs on water-efficient landscaping.	High	S, W, L	9	💧	💧	💧	💧		$	$	$	√	√	
LI-3: Establish a statewide training and certification program for irrigation design and installation professionals.	High	S, I	9	💧	💧	💧	💧		$	$	$	√	√	
LI-4: Develop environmentally sound guidelines for the review of site plans	Med.	S, L	8	💧	💧	💧	💧		$	$	$	√		
LI-5: Conduct applied research to improve turf and landscape water conservation	Med.	S, I	8	💧	💧	💧	💧		$	$		√	√	
LI-6: Establish a training and certification program for landscape maintenance workers.	Med.	S, W, I	7	💧	💧	💧	💧		$	$		√		
LI-7: Evaluate the use of water budgeting as an effective water conservation practice	Low	W, L	6	💧	💧	💧	💧		$			√		
LI-8: Evaluate the need to establish consistent statewide watering restrictions for landscape irrigation	Low	W, L, I	6	💧	💧	💧			$	$		√		

[a] Bolded alternatives from FDEP Basic List of Water Conservation Alternatives to be Considered (FDEP, 2003).
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Table 2. Recommended Water Conservation Alternatives (Continued).

Water Conservation Alternative[a]	**Priority**	**Respon-sible Entity**	**Total Score**	**Amount of Water Saved (1 to 5)**[b]					**Cost Effectiveness (1 to 3)**[c]			**Ease of Implementing (1 to 3)**[d]		
WATER PRICING														
WP-1: Phase in conservation rate structures	High	S, W, L	10	💧	💧	💧	💧	💧	$	$	$	√	√	
WP-2: Require drought rates as part of utility conservation rate structures	Med.	S, W, L	8	💧	💧	💧			$	$	$	√	√	
WP-3: Consider using market principles in the allocation of water, while still protecting the fundamental principles of Florida water law	Med.	S, W, I	7	💧	💧	💧			$	$	$	√		
WP-4: Improve cost-effectiveness in the next cycle of regional water supply plans	Med.	W	7	💧	💧				$	$	$	√	√	
WP-5: Phase in informative billing	Med.	S, W, L	7	💧	💧				$	$	$	√	√	
WP-6: Require more measurement of water use, including metering and sub-metering		S, W, L												
a) Sub-metering of new multi-family residences	Med.	S, L	7	💧	💧	💧			$	$		√	√	
b) Sub-metering retrofit of existing multi-family residences	Low	S, L	6	💧	💧	💧	💧		$			√		
WP-7: Adopt additional state guidance on water supply development subsidies	Low	S, W	6	💧	💧				$	$		√	√	

[a] Bolded alternatives from FDEP Basic List of Water Conservation Alternatives to be Considered (FDEP, 2003).
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Table 2. Recommended Water Conservation Alternatives (Continued).

Water Conservation Alternative[a]	**Priority**	**Respon-sible Entity**	**Total Score**	**Amount of Water Saved (1 to 5)**[b]					**Cost Effectiveness (1 to 3)**[c]			**Ease of Implementing (1 to 3)**[d]		
INDUSTRIAL/ COMMERCIAL/ INSTITUTIONAL														
ICI-1: Consider establishing a “Conservation Certification” Program	High	S, W, I	10	💧	💧	💧	💧		$	$	$	√	√	√
ICI-2: Consider a range of financial incentives and alternative water supply credits	High	F, S	10	💧	💧	💧	💧		$	$	$	√	√	√
ICI-3: Consider cooperative funding for the use of alternative technologies to conserve water	High	I	9	💧	💧	💧	💧		$	$	$	√	√	
ICI-4: Implement additional water auditing programs	Med.	S, W	8	💧	💧	💧	💧		$	$		√	√	
ICI-5: Promote utilization of reclaimed water	Med.	S, W, L, I	8	💧	💧	💧	💧		$	$		√	√	
ICI-6: Investigate methods of assuring that large users from public suppliers have the same conservation requirements as users with individual permits	Low	W, L	6	💧	💧	💧			$	$		√		
INDOOR WATER USE														
IWU-1: Expand programs to replace inefficient toilets	High	W, L	10	💧	💧	💧	💧	💧	$	$	$	√	√	
IWU-2: Require that inefficient plumbing fixtures be retrofitted at time of home sale	High	S, L, I	9	💧	💧	💧	💧		$	$	$	√	√	
IWU-3: Provide incentives to retrofit inefficient home plumbing fixtures	High	W, L	9	💧	💧	💧	💧		$	$	$	√	√	

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Water Conservation Alternative[a]	**Priority**	**Respon-sible Entity**	**Total Score**	**Amount of Water Saved (1 to 5)**[b]					**Cost Effectiveness (1 to 3)**[c]			**Ease of Implementing (1 to 3)**[d]		
IWU-4: Support national dishwasher and clothes washer standards; offer incentives for purchasing efficient washers	High	S, W, L	9	💧	💧	💧	💧		$	$	$	√	√	
IWU-5: Create a water auditor inspection program for the sale of new and existing homes, supported by a refundable utility service fee	Med.	S, L	8	💧	💧	💧	💧		$	$	$	√		
IWU-6: Coordinate and expand the statewide water conservation campaigns	Med.	S, W, L	8	💧	💧	💧	💧		$	$		√	√	
IWU-7: Evaluate the potential for gray water use	Low	S	5	💧	💧	💧			$			√		
IWU-8: Investigate the potential for cisterns	Low	L	4	💧	💧				$			√		
REUSE OF RECLAIMED WATER														
RW-1: Encourage metering and volume-based rate structures for reclaimed water service	High	S, W	10	💧	💧	💧	💧	💧	$	$	$	√	√	
RW-2: Education and Outreach	High	S, W, L	9	💧	💧	💧	💧		$	$		√	√	√
RW-3: Facilitate seasonal reclaimed water storage (including ASR)	High	S, W, L	9	💧	💧	💧	💧		$	$	$	√	√	
RW-4: Link reuse to regional water supply planning	High	S, W	9	💧	💧	💧	💧		$	$	$	√	√	
RW-5: Implement viable funding programs	High	S, W	9	💧	💧	💧	💧	💧	$	$		√	√	

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Water Conservation Alternative[a]	**Priority**	**Respon-sible Entity**	**Total Score**	**Amount of Water Saved (1 to 5)**[b]					**Cost Effectiveness (1 to 3)**[c]			**Ease of Implementing (1 to 3)**[d]		
RW-6: Promote agency support of groundwater recharge and indirect potable reuse	High	S, W	9	💧	💧	💧	💧	💧	$	$		√	√	
RW-7: Encourage reuse in Southeast Florida	High	S, W	9	💧	💧	💧	💧	💧	$	$		√	√	
RW-8: CUP incentives for utilities that implement reuse programs	Med.	S, W	8	💧	💧	💧	💧		$	$		√	√	
RW-9: Encourage use of supplemental water supplies	Med.	S, W, L	7	💧	💧	💧			$	$		√	√	
RW-10: Assist in ensuring economic feasibility for reuse utilities and end users	Med.	W, L, I	7	💧	💧	💧			$	$		√	√	
RW-11: Encourage reuse system inter-connects	Med.	S, W	7	💧	💧	💧			$	$		√	√	
RW-12: Enable redirection of existing reuse systems to more desirable reuse options	Low	S, W	6	💧	💧	💧			$	$		√		
RW-13: Facilitate permitting of backup discharges	Low	S	6	💧	💧				$	$		√	√	

[a] Bolded alternatives from FDEP Basic List of Water Conservation Alternatives to be Considered (FDEP, 2003).

[b] A score of 1 indicates the least water saved, 5 the most.

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[d] A score of 1 indicates relatively difficult to implement, 3 relatively easy.

WATER CONSERVATION

Water conservation refers to reductions in water use. Practices and technologies that provide water uses are broken down into two categories: 1) long-term, permanent reductions, and 2) short-term, temporary reductions. Long-term reductions require implementation of technologies, such as ultralow flow devices, that reduce water use, while satisfying the needs of consumers. This distinguishes them from the short-term water conservation measures and cutbacks that are required of users during water shortage situations or when short-term problems with the supply system capacity occur.

Water conservation is also known as demand management, which addresses permanent water use efficiencies at the point of demand. The permanent water use reductions resulting from long-term conservation technologies provide many benefits, such as reducing impacts on the environment and water resources.

Mandatory Water Conservation Measures

The District's consumptive use permitting rules require planning and implementation of water conservation measures by public water supply utilities (and associated local governments), commercial/industrial users, landscape and golf course users, and by agricultural users. Examples of requirements include adoption of local government ordinances that affect irrigation hours, landscaping and plumbing fixtures, leak detection, rate structures and public education. All of these requirements apply to users required to obtain individual water use permits. Water use (consumptive use) permitting is further discussed in **Chapter 4** (Regulation).

Public Water Supply Utilities

All permit applicants for a potable public water supply permit must submit a water conservation plan at the time of permit application. Utilities operated by private entities and those public utilities providing service to an area beyond their political boundary are required to document their request to local governments within their service area to adopt conservation ordinances.

The conservation plan must address:

- Adoption of an irrigation hours ordinance.
- Adoption of a Xeriscape™ landscape ordinance.
- Adoption of an ultralow volume fixtures ordinance.
- Adoption of a rain sensor device ordinance.
- Adoption of a water conservation based rate structure.
- Implementation of a leak detection and repair program.

- Implementation of a water conservation public education program.
- An analysis of reclaimed water feasibility.

The mandatory water conservation program requires that each utility evaluate or plan and implement all elements where applicable. Utilities must rely on local governments to codify water conservation ordinances. Depending on the demographics, housing characteristics and location of the service area, utilities can choose to demonstrate which water conservation activities are more cost-effective for their situation and emphasize implementation of those activities in their conservation plan.

Adoption of an Irrigation Hours Ordinance

The ordinance limits all lawn irrigation to the hours of 4:00 P.M. to 10:00 A.M. because irrigation during daytime hours is less efficient. Sunlight and increased winds during daytime hours cause water to evaporate before reaching the ground or to blow onto impervious surfaces, such as sidewalks, roads and driveways. Wind also causes the water that reaches the plants to be unevenly applied. In addition to changing the time of irrigation, users should water more deeply but less frequently. Public education programs also contribute to the effectiveness of irrigation ordinances by informing irrigators how they may reduce applications, while still meeting the water requirements of plants.

The permit applicant or enacting local government may adopt an ordinance that includes exemptions from the irrigation time restrictions for the following circumstances:

- Irrigating with a microirrigation system.
- Reclaimed water end users.
- Preparing for irrigation of new landscape.
- Watering in of chemicals, including insecticides, pesticides, fertilizers, fungicides and herbicides, when required by label, recommended by the manufacturer or implementing best management practices.
- Maintenance and repair of irrigation systems.
- Irrigating with low volume hand watering, including watering by one hose attended by one person, fitted with a self-canceling or automatic shut off nozzle or both.
- Irrigating with 75 percent or more water recovered or derived from an aquifer storage and recovery system.

Adoption of a Xeriscape™ Landscape Ordinance

Xeriscape™ is defined in the Florida Legislature as:

> Paragraph 373.185(1)(b), F.S. "Xeriscape™" or "Florida-friendly landscape" means quality landscapes that conserve water and protect the environment and are adaptable to local conditions and which are drought tolerant. The principles of Xeriscape™ include planning and design, appropriate choice of plants, soil analysis which may include the use of solid waste compost, efficient irrigation, practical use of turf, appropriate use of mulches, and proper maintenance.

The legislation requires that the water management districts establish incentive programs and provide minimum criteria for qualifying Xeriscape™ codes. These codes prohibit the use of invasive exotic plant species, set maximum percentages of turf and impervious surfaces, include standards for the preservation of existing natural vegetation and require a rain sensor for automatic sprinkler systems. District rules, as mandated by the legislature, require that all local governments consider a Xeriscape™ ordinance and that the ordinance be adopted if the local government finds that Xeriscape™ would be of significant benefit as a water conservation measure relative to the cost of implementation. The Xeriscape™ landscape ordinance will affect new construction and landscapes undergoing renovation that require a building permit.

The District has found the implementation and use of Xeriscape™ landscaping, as defined in Section 373.185, F.S., contributes to the conservation of water. The District further supports adoption of local government ordinances as a significant means of achieving water conservation through Xeriscape™ landscaping.

Adoption of an Ultralow Volume Fixture Ordinance

This measure requires adoption of an ordinance that requires the installation of ultralow volume (ULV) plumbing fixtures in all new construction. The District's water use permit regulations specify that the fixtures have a maximum flow volume when the water pressure is 80 pounds per square inch (psi) as follows: toilets, 1.6 gal/flush; showerheads, 2.5 gal/min.; and faucets, 2.2 gal/min. at 60 psi. The previous standard for plumbing devices (before September 1983) included: toilets, 3.5 gal/flush; showerheads, 3.0 gal/ min.; and faucets, 2.5 gal/min. These District regulations are consistent with the maximum water use allowed for showerheads and faucets manufactured after January 1, 1994 (U.S. Code: Title 42, Section 6295 of the federal *Energy Policy Act*) and conform to current Building Construction Standards (Chapter 553, F.S.).

Ultralow volume fixtures save water by using less water, while providing a sufficient level of service to the user. The water savings made by installing ULV fixtures are estimated at 8,670 gallons per toilet a year. By comparison, 9,125 gallons per shower can be saved over a year (**Table 3**).

Table 3. Representative Water Use and Cost Analysis for Ultralow Volume Fixtures.

Housing Stock Characteristic	Conservation Measure	Water Savings per Retrofit Device	Cost per Device	Cost per 1,000 gallons
Housing Built Before 1984	Showerhead retrofit	3.5 gallons/minute	$20	$.06/1,000
	Toilet retrofit	4.4 gallons per flush	$200	$.25/1,000
Pre-1992 Outdoor Irrigation Systems Without Rain Sensors	Rain sensor installation	74 gallons/day	$68	$.25/1,000

Source: Hampton Roads Water Efficiency Team, Water Wise Guide, 2000. Available from: http://www.hrwet.org
Source: U.S. General Accounting Office: "Water Infrastructure: Water-Efficient Plumbing Fixtures Reduce Water Consumption and Wastewater Flows," 2000. Available from: http://www.gao.gov
Source: U.S. Department of Energy Plumbing Manufacturers Institute, "How to Buy a Water-Saving Replacement Toilet," 2000. Available from: http://www.eere.energy.gov

Adoption of a Rain Sensor Device Ordinance

This measure involves adoption of an ordinance that requires any person purchasing or installing an automatic sprinkler system to install, operate and maintain a rain sensor device or an automatic switch. This equipment will override the irrigation cycle of the sprinkler system when adequate rainfall has occurred.

As with ULV fixtures, rain sensor devices save water by using less water, while providing a sufficient level of service to the user. The water savings made by installing rain sensor devices are estimated at 26,882 gallons per housing unit per year (**Table 4**).

Table 4. Representative Water Use and Cost Analysis for Rain Sensor.

Representative Water Use	Rain Sensor
Cost/unit or visit ($)	$68.00
Acres/unit	0.11
Water savings (inches/year)	9.0
Water savings (gallons/year)	26,882
Life (years)	10
Water savings/life (gallons)	268,825
Cost/1,000 gallons saved ($)	$0.253

Note: These savings are based on 180 ½-inch irrigations per year. An analysis of 37 years of daily rain data from NOAA at Fort Pierce and Stuart show 10% of the days had greater than or equal to ½-inch of rain. These savings are independent of turf irrigation requirements.

Adoption of a Conservation Rate Structure

A conservation rate structure is a rate structure used by utilities that provides a financial incentive for users to reduce demands. Water conservation rates generally involve:

- Increasing the block rate, where the marginal cost of water to the user increases in two or more steps as water use increases.
- Seasonal pricing, where water consumed in the season of peak demand, such as from October through May, is charged a higher rate than water consumed in the off peak season.
- Quantity based surcharges.
- Time of day pricing.

Users faced with higher rates will often achieve water conservation by implementing a number of the conservation measures discussed in this chapter. The most frequently used conservation rate structure used by utilities is increasing block rates. This rate structure generally is expected to have the largest impact on heavy irrigation users. The responsiveness of the customers to the conservation rate structure depends on the existing price structure, the water conservation incentives of the new price structure, the customer base and their water uses.

Adoption of a Utility Leak Detection and Repair Program

The District requires implementation of leak detection programs by utilities with unaccounted for water losses greater than 10 percent. The leak detection program must include water auditing procedures, and infield leak detection and repair program. The program description should include the number of labor hours devoted to leak detection, the type of leak detection equipment used and an accounting of the water saved through leak detection and repair.

Implementation of a Water Conservation Public Education Program

Public information, as a water conservation measure, involves a series of reinforcing activities and/or messages to:

- Inform citizens of opportunities to reduce water use.
- Establish a level of awareness on the benefits of practicing water conservation.
- Publicize the conservation options being promoted by the District, local governments and utilities.

All users can be brought to an educated level on local and regional conservation efforts. These efforts are typically targeted at the users with the most potential for participation, including domestic indoor and outdoor uses. This gives the public a means to take action in implementing conservation behavior and techniques, such as installing and maintaining water saving devices.

Analysis of Reclaimed Water Feasibility

For potable public water supply utilities that control a wastewater treatment plant, an analysis of the economic, environmental and technical feasibility of making reclaimed water available is required.

Commercial/Industrial Users

The District's regulations require that all individual commercial/industrial permit applicants submit a conservation plan.

Conservation plans must include:

- An audit of water use.
- Implementation of cost-effective conservation measures.
- An employee water conservation awareness program.
- Procedures and time frames for implementation.
- The feasibility of using reclaimed water.

Landscape and Golf Course Users

Landscape and golf course permittees are required to use Xeriscape™ landscaping principles for new projects and modifications when they find Xeriscape™ to be cost-effective. They are also required to install rain sensor devices or switches, irrigate between the hours of 4:00 p.m. and 10:00 a.m. and analyze the feasibility of using reclaimed water. There are, however, exceptions to the irrigation hour limitations in the rule, which provide for protection of the landscape during stress periods and help assure the proper maintenance of irrigation systems.

Agricultural Users

Citrus, vegetable and container nursery permittees are required by the SFWMD to use microirrigation or other systems of equivalent efficiency. This applies to new installations or upon modifications to existing irrigation systems. The permittees are also required to analyze the feasibility of using reclaimed water.

Microirrigation Systems

Microirrigation systems achieve water savings by directly applying a high percentage of water to the root zone of the crop in controlled amounts, so losses through deep percolation, drainage, etc., are reduced. In addition, application of water is limited to areas not underlain by the root zone. Installation of microirrigation systems, or systems of equivalent efficiency, is required under SFWMD permitting rules for new citrus and container nurseries. Additional water savings can be achieved by the use of microirrigation systems on crops (such as vegetables), and by retrofitting irrigation systems for existing citrus and nursery crops.

Conversion of existing seepage irrigated citrus to microirrigation is a significant source of water savings (**Table 5**). **Table 5** summarizes the cost and potential water savings from one acre of conversion. The water savings from converting 25,000 acres of citrus from flood irrigation with 50 percent efficiency, to microirrigation with 85 percent efficiency would result in water saving of approximately 6 billion gallons per year (BGY) or 15.8 million gallons per day (MGD). The analysis illustrates that given the large volumes of water used for irrigation by agriculture; water conservation savings (which can be achieved at a reasonable cost) are often extremely cost-effective compared to the costs of developing additional water supplies.

It is estimated by Institute of Food and Agricultural Service (IFAS) that the initial cost to install a microirrigation system on citrus is $1,000 per acre and the system would have estimated annual maintenance costs of $25 per acre per year (IFAS, 1993).

Table 5. Irrigation Costs and Water Use Savings Associated with Conversion of Citrus from Seepage Irrigation to Low Volume Irrigation.

Initial cost ($/acre)	$1,000.00
Operating cost ($/acre)	$25.00
Water savings (inches per year)	8,519
Water savings (gallons per year)	230,805
Life (years)	20
Cost over life ($)	$1,500.00
Water savings over life (gallons)	4,616,100
Cost/1,000 gallons saved ($)	$0.33

Source: Institute of Food and Agricultural Sciences, 1993.

Supplementary Water Conservation Measures

Supplementary water conservation measures are those measures that have water reduction benefits, but are not required by the District's water conservation rule. Supplementary measures enhance the mandated conservation measures by further reducing water demands.

Urban Users

Supplementary measures for urban users may include outdoor conservation measures as those are usually the most cost-effective, and outdoor water use is often the largest component of use for urban water users.

The savings per unit of cost associated with the outdoor conservation measures are generally greater than those for indoor conservation measures, primarily due to the larger volumes of water used. For example, if 10,000 showerheads were retrofitted in an area, this could result in a water savings of 182 million gallons per year (MGY) or 0.50 MGD. Likewise, if 10,000 irrigation systems were retrofitted with rain sensors, this could result in a water savings of over 2 BGY (5.73 MGD). Audits and subsequent retrofits can also benefit water utility customers by reducing water use, and in turn reducing water bills.

Indoor Audits and Water-Efficient Technology

The *1992 Energy Policy Act* stipulated national maximum allowable water-flow rates for indoor plumbing fixtures. These fixtures were required in new construction from the inception of the Act. However, existing housing can significantly reduce water use by switching to the more efficient fixtures.

Indoor audits provide information and services directly to households and other urban water users to achieve greater efficiency on appliances that use indoor water. This option generally includes inspections to locate leaks, determine if plumbing devices are operating properly, repair minor problems and provide information on conservation measures and devices. In some cases, a retrofit program will include installation of ULV showerheads and toilet devices.

Utilities and local governments can devise programs that carefully target the most cost-effective applications of these measures. In retrofit programs, one option is to target residences with high water consuming fixtures, generally older housing.

The cost-effectiveness of retrofitting older homes is enhanced by the fact that many of these homes have fewer bathrooms and fixtures. The larger the number of people using a water saving device, the more cost-effective and water conserving the retrofit. An appropriate strategy would be to target homes with large numbers of persons per fixture for complete retrofit, and other homes for retrofit of only the most heavily used fixtures. This suggests that a particularly suitable target for retrofit programs are public rest rooms and other facilities that have high use rates.

Landscape Audits and Water-Efficient Technology

Landscape audits are measures that improve the efficiency of irrigation systems, and include services to determine if the irrigation system is operating properly. Improving the efficiency of irrigation systems may include adjusting irrigation timers (to assure that a water conserving schedule is being followed), replacing sprinkler heads (to assure that the system is providing adequate coverage and not wasting water by irrigating impervious surfaces), recalibrating irrigation systems, and installing rainfall sensing/irrigation control devices.

Utilities and water management agencies generally implement landscape audits. Because of the large outdoor component of water use in South Florida, irrigation audits can be especially effective. Outdoor water audits are particularly important due to the peaking of outdoor demand during periods of low rainfall, with maximum stress on water resources.

Landscape retrofit measures provide information and incentives for users to implement physical changes to their landscapes and irrigation systems. Devices suitable for landscape retrofit include those that prevent unnecessary irrigation by detecting recent rainfall or sensing soil moisture. Other retrofit options include replacing existing landscaping with site appropriate plants and practicing landscape management, which includes rezoning irrigation systems and mulching.

To assist homeowners with reducing outdoor irrigation, mobile irrigation laboratories (MILs) perform audits to evaluate the potential for saving water. An urban MIL typically performs 140 evaluations per year (**Table 6**). The urban MILs in south Florida typically save 0.43 MGD. Saving water also results in saving money ($2.25 per 1,000 gallons). The program is maintained by a partnership between the SFWMD, the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA–NRCS), the Florida Department of Agricultural and Consumer Services (FDACS) and various soil and water conservation districts. Audits are provided at no cost to the homeowner.

Table 6. Costs and Water Savings Associated with Urban Mobile Irrigation Labs.

Representative Water Use	Mobile Irrigation Lab
District Cost (/lab/year)	$56,000
Evaluations (/lab/year)	140
Water Savings (MGD)[a]	0.43

a. Based on 1998–2002 evaluation data from all south Florida urban MILs.

Public Water Supply Utilities

Filter Backwash Recycling

This measure encourages water utilities using filter systems that are cleaned by backwashing (cleaning the filter by reversing the flow of water) to recycle the backwash water to the head of the treatment plant for retreatment.

Distribution System Pressure Control

Pressure control measures in potable water distribution systems reduce water use, while providing acceptable water pressures to customers. System pressure should keep water-using devices working properly, while providing for public health and fire safety needs. Pressure reduction valves and interconnecting and looping utility mains, are methods used to equalize and, therefore, stabilize overall operating pressure. Unlike the pressure reduction efforts during water shortages, which call for reductions in pressures to levels necessary to meet minimums for fire flow, these changes target reductions at locations where pressures are inconsistently high within the system.

There are numerous benefits to an optimized or stabilized pressure system. High pressures increase loss of water through leaks, and increase use by the end user, especially when water use is prescribed by time. High pressures cause increases in water application and can cause atomization of the spray, which reduces irrigation efficiency. Low pressures, however, reduce the areas covered by poorly designed sprinkler systems, resulting in stress to the uncovered areas. This may encourage users to increase irrigation time in an attempt to improve the results of the irrigation efforts.

Wastewater Utility Infiltration Detection and Repair

Wastewater utility infiltration detection and repair includes estimating and detecting infiltration of groundwater or surface water into wastewater collection systems and repair efforts to reduce the infiltration. Reducing infiltration of groundwater prevents waste by allowing the groundwater to be used for other purposes.

Agricultural Users

Agricultural Audits and Water-Efficient Technology

Growers are encouraged to adopt irrigation management practices that conserve water. Irrigation management practices and technology are interdependent. For instance, a change in the type of irrigation system will generally require a change in irrigation scheduling to achieve water conservation, while maintaining crop yield and economic return. An additional factor in agricultural water conservation is potential energy savings. Costs for diesel fuel or electricity used for pumping water are energy related and will be reduced if water conservation management practices are employed.

To assist growers with agricultural irrigation, mobile irrigation laboratories perform audits on their irrigation systems. An agricultural MIL typically performs 110 evaluations per year (**Table 7**). The agricultural MILs in south Florida typically save 8.54 MGD. The program maintained by a partnership between the SFWMD, the USDA–NRCS, FDACS and various soil and water conservation districts. Audits are provided at no cost to the grower.

Table 7. Cost and Water Savings Associated with Agricultural Mobile Irrigation Labs.

Representative Water Use	Mobile Irrigation Lab
District Cost (/lab/year)	$104,000
Evaluations (/lab/year)	110
Water Savings (MGD)[a]	8.54

a. Based on 1998-2002 evaluation data from all south Florida agricultural MILs.

WATER SOURCE OPTIONS – SUPPLY MANAGEMENT

As previously mentioned, water source options are also referred to as supply management. Supply management consists of water source options that could be used to meet a specific demand. In some areas, these options are considered conventional sources, while in other areas they would be considered alternative water supply sources. For example, the Floridan Aquifer is the primary source of water in the Kissimmee Basin where its quality is fresh. However, in most of the other areas in the District, the Floridan Aquifer is considered an alternative source because its water quality is brackish and requires desalination treatment or blending with a freshwater source prior to treatment or use.

In addition, some sources that have been historically considered alternative are now becoming commonplace. For instance, the use of brackish water from the Floridan Aquifer in many regions of the District, as in the Lower West Coast, where use of freshwater aquifers has been maximized in much of the coastal portions of the region. Over 50 percent of the water allocated for public water supply in this region is for brackish water from the Floridan Aquifer. Depending on the region, there is a variety of water source options that can be utilized to meet water demands. These source options include:

- Groundwater sources
  - Surficial Aquifer
  - Intermediate Aquifer
  - Floridan Aquifer
- Reclaimed Water
- Seawater
- Storm water
- Storage
  - Aquifer storage & recovery
  - Drainage wells
  - Regional & local retention
  - Reservoirs
- Surface water
- Utility interconnects

Water Source Option Cost Information

Cost information is included for most of the water sources options below. Treatment technologies and their associated cost are presented in **Chapter 5** of this document. Unless otherwise noted, cost information presented in **Chapters 3** and **5** is updated information from the St. John's River Water Management District's (SJRWMD) Special Publication SJ97-SP3 titled, *Water Supply Needs and Sources Assessment—Alternative Water Supply Strategies Investigation—Water Supply and Wastewater Systems Component Cost Information*. The cost information contained in the SJRWMD document was updated to project 2005 dollars using a Florida Department of Environmental Protection (FDEP) and water management district agreed upon, projected 2005 Construction Cost Index (see memo dated April 3, 2003 located in Appendix C) for the purposes of this Plan Update. The cost information provides a consistent set of definitions and criteria for the development of comparable planning level, life cycle, cost estimates for water supply and wastewater treatment alternatives. Below are definitions of the cost terms used in this cost information.

Construction Costs

The construction costs developed for each of the water supply and wastewater treatment systems are the total amounts expected to be paid to a qualified contractor to build the required facilities. These values include all material costs, equipment costs, installation costs and taxes. Unless otherwise noted, the construction costs for treatment components do not include factors for peak flow.

Non-Construction Capital Costs

The non-construction costs are 45 percent of the construction costs and account for engineering design, permitting, administration and construction contingency associated with the constructed facilities. The 45 percent non-construction costs are divided into three parts, an engineering cost of 15 percent of the construction costs; an administrative cost of 10 percent of the construction cost; and a general contingency of 20 percent of the construction cost.

Land and Acquisition Costs

Recommended values are used for the purpose of land cost estimations and are in the form of dollars per acre or dollars per square foot. A $100,000 per acre value for land was used unless otherwise noted. The land area required and the cost associated with the land is included as a part of the total capital cost for each of the water supply and wastewater system components. In addition to the cost of the land, a land acquisition cost of 25 percent of the land value is included to account for the cost of engineering, administrative and legal services associated with the land acquisition process.

Total Capital Costs

The total capital costs for each of the water supply and wastewater system components are the sum of the construction costs, non-construction costs, land value and land acquisition costs.

Operation and Maintenance (O&M) Costs

The Operations and Maintenance (O&M) costs are the estimated costs of operating and maintaining the water supply or wastewater treatment system components each year. These costs include all energy costs, chemical costs, labor costs, etc. The O&M costs are based on annual average flow conditions.

Equivalent Annual Costs

The equivalent annual costs are the total life cycle costs of the system component based on the service life of the component and the time value of money. The time value of money used for the purpose of this investigation is seven percent and the service lives of the components are presented in document referenced above. The annual O&M costs associated with the system component are also included in the equivalent annual cost.

Unit Costs

Unit costs include that portion of the annual O&M costs that vary with the production rate such as energy costs and chemical costs. The unit costs are expressed in terms of dollars per 1,000 gallons.

Groundwater Sources

Significant amounts of water demands within the District are met with groundwater sources, especially urban demands. The hydrogeology of south Florida is best defined as a series of layered aquifers and aquitards that vary in thickness and depth. This includes both semi-confined and unconfined aquifers. There are three primary water producing aquifer systems that groundwater is withdrawn from in each of the planning regions: Surficial Aquifer System (SAS), Intermediate Aquifer System (IAS) and the Floridan Aquifer System (FAS). These systems typically do not extend over the entire District, are not present in all regions and vary from region to region. The Floridan Aquifer System does exist throughout the District. Within an individual aquifer, hydraulic properties and water quality may vary vertically and horizontally.

Surficial Aquifer System (SAS)

The SAS is typically found at depths from land surface to 200 feet below land surface. This includes the SAS in the Upper East Coast (UEC) and Kissimmee Basin (KB) Planning Regions, the Biscayne Aquifer in the Lower East Coast (LEC) Planning Region and the Water Table and lower Tamiami Aquifers in the Lower West Coast (LWC) Planning Region.

Intermediate Aquifer System (IAS)

The IAS is a confining unit in most of the District producing very little water. The IAS is used for water supply on a very limited basis, except for the LWC Region. In the LWC Region, the IAS includes two producing zones, the Sandstone and mid-Hawthorn Aquifers. These aquifers can be found from 50 to almost 400 feet below land surface, depending on the location.

Floridan Aquifer System (FAS)

The FAS is the deepest of the aquifers used for water supply in the District. The water quality in the FAS decreases significantly from Orlando to Miami or Naples. Within the FAS are multiple permeable intervals, or producing zones, sandwiched between low permeability confining materials. The quality of water in the FAS deteriorates to the south, increasing in hardness and salinity. Salinity also increases with depth, making the deeper producing zones less suitable for development than those near the top of the system. In the KB Region, the FAS is the primary source of fresh water for all uses. However, water from the FAS requires desalination treatment south of central Okeechobee County. In addition, the FAS is artesian (flows at land surface without a pump) in some portions of the District. The water producing formations of the FAS in the Orlando area can be found between 80 and 1,500 feet below land surface. The water producing formations of the FAS currently used for water supply south of central Okeechobee County can be found from 600 feet to over 1,800 feet depending on the location.

In 2003, there were over 25 regional water suppliers in south Florida using reverse osmosis of brackish water from the Floridan Aquifer to meet potable water demands. These utilities and several others, plan to use the Floridan to meet their future water needs. In addition, several golf courses in south Florida have also tapped the Floridan Aquifer using reverse osmosis to meet their irrigation needs. Many citrus growers in the UEC Region also depend on the Floridan Aquifer when surface water availability becomes limited. Currently, use of a brackish water source is exempt from District water shortage declarations.

Groundwater Estimated Costs

Expansion of an existing public water supply wellfield is usually selected by a utility when additional raw water is required. Groundwater supply systems are composed of wellfields and their related features, such as wells and pumps. The cost of a well is a function of diameter and depth. **Figure 4** & **5** provide the well drilling construction costs and the well drilling construction and non-construction costs combined for different diameters and depths. These costs include drilling, casing to District standards, minimal logging, pump test and final wellhead. Well equipment costs are presented in **Table 8** and include pumps, valves, fittings, metering, a well house structure and electrical controls as well installation and taxes. The O&M costs include normal maintenance of the well including equipment, energy and labor.

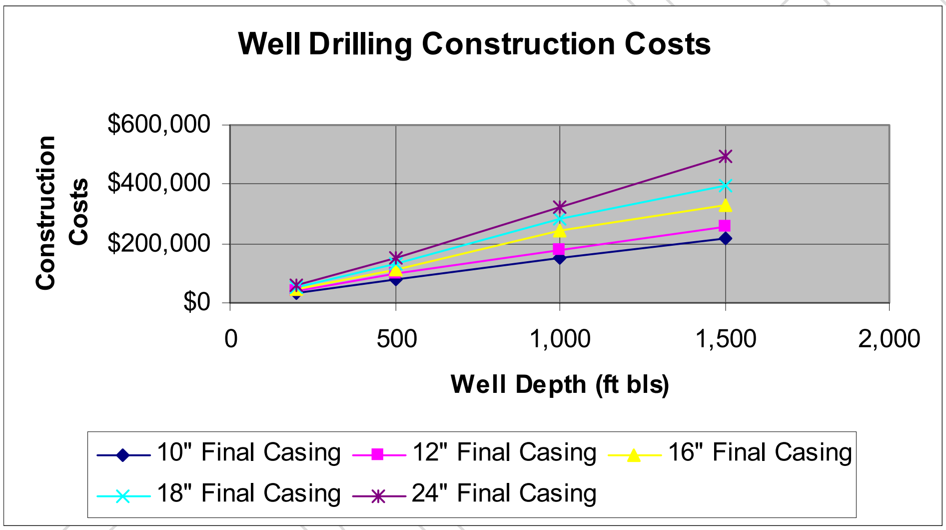


Figure 4. Well Drilling Construction Costs.
Source: Diversified Drilling Corporation. Fax dated October 23, 2003.

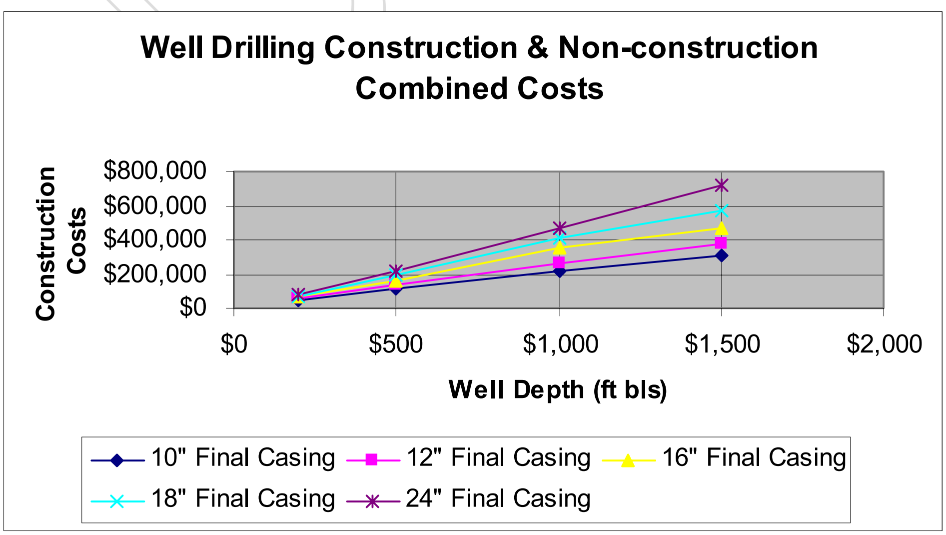


Figure 5. Well Drilling Construction and Non-Construction Combined Costs.
Source: Diversified Drilling Corporation. Fax dated October 23, 2003.

Table 8. Well Equipment Cost Estimates.

Capacity (MGD)	Construction Cost	Non-Construction Cost	Total Capital Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$49,429	$22,243	$71,671	$27,628	$34,393	$0.09
2	$59,946	$26,976	$86,921	$43,231	$51,435	$0.07
3	$69,788	$31,404	$101,192	$64,424	$73,975	$0.07
4	$80,442	$36,199	$116,641	$86,306	$97,316	$0.07
5	$90,846	$40,881	$131,727	$103,433	$115,867	$0.06

Groundwater wells are limited in the amount of water they can yield by the rate of water movement in the aquifers, the rate of recharge, the storage capacity of the aquifer, environmental impacts and proximity to sources of contamination and saltwater intrusion. These factors together determine the number, size and distribution of wells that can be developed at a specific site. Long-range planning by the water suppliers to identify future wellfield sites, and to protect those future sites from contamination by controlling land use activities within the influence of the wellfield, is important to ensure satisfactory future water supply.

Reclaimed Water

Reclaimed water is wastewater that has received at least secondary treatment and is reused after flowing out of a wastewater treatment plant (Chapter 62-610, F.A.C.). Reuse is the deliberate application of reclaimed water for a beneficial purpose, in compliance with the FDEP and water management district rules. Potential uses of reclaimed water include landscape and agricultural irrigation, groundwater recharge, industrial uses, environmental enhancement and fire protection.

The State of Florida encourages and promotes the use of reclaimed water. The Water Resource Implementation Rule (Chapter 62-40 F.A.C.) requires the FDEP and water management districts advocate and direct the reuse of reclaimed water as an integral part of water management programs, rules and plans. The District requires all applicants for water use permits to use reclaimed water unless the applicant can demonstrate that it is not feasible to do so.

In 2002, in the SFWMD service area, there were 110 wastewater facilities that reused over 200 MGD of reclaimed water for a beneficial purpose (FDEP, 2002). This reuse accounted for 26 percent of the total 788 MGD of wastewater treated in the District. The remaining 588 MGD of treated wastewater was disposed of by deep well injection or discharge to the ocean. **Table 9** illustrates the percent of wastewater treated for reuse in 2002 by planning region. The Kissimmee Basin had the highest percentage of reuse (100%), followed by the Lower West Coast (89%), the Upper East Coast (52%) and the Lower East Coast (10%).

Table 9. 2002 SFWMD Reuse by Planning Region.

2002 SFWMD Reuse By Planning Region[a]					
Planning Region / County	**WWTF Capacity (MGD)**	**WWTF Flow (MGD)**	**Reuse Capacity (MGD)**	**Reuse Flow (MGD)**	**Percent Reuse[b]**
Lower East Coast (LEC)					
Broward	243.33	191.62	20.69	11.04	6
Miami-Dade	358.81	316.20	24.39	19.09	6
Monroe	12.23	5.64	0.76	0.33	6
Palm Beach	160.79	117.27	61.18	30.02	26
LEC Total	775.16	630.73	107.02	60.48	10
Lower West Coast (LWC)					
Collier	34.77	27.91	37.08	23.19	83
Hendry	2.33	1.66	2.33	1.65	99
Lee	67.38	40.01	50.12	37.06	93
LWC Total	104.48	69.58	89.53	61.90	89
Upper East Coast (UEC)					
Martin	12.78	7.16	9.10	5.19	72
St. Lucie	18.38	10.95	9.93	4.20	38
UEC Total	31.16	18.11	19.03	9.39	52
Kissimmee Basin (KB)					
Okeechobee	1.40	0.77	1.26	0.77	100
Orange	78.69	49.08	113.38	49.24	100
Osceola	26.04	18.64	40.99	18.23	98
Polk	1.20	100	0.94	0.98	98
KB Total	107.33	69.49	156.57	69.22	100
District Totals	1018.13	787.91	372.15	200.99	26
State Totals	2219.21	1508.63	1161.68	584.49	39

a. Data obtained from FDEP Reuse Inventory (2003).
b. Reuse Flow divided by WWTF Flow times 100.

Reuse needs to be encouraged in some parts of the District, while conservation and efficient use of reclaimed water needs to be promoted in other parts. Reuse in the LEC Region has lagged behind the rest of the District and the state. Only 10 percent of the wastewater treated in this region is reused. The 570 MGD that is not reused in this region currently is disposed of through ocean outfalls and deep injection wells. This is potentially reusable water with the possible exception of 260 MGD containing elevated salt levels. Palm Beach County currently reuses over 26 percent of their wastewater, and with the projects underway in the County, this is expected to increase over the next several years. Palm Beach County has adopted a mandatory reuse ordinance that requires all new development in the area defined in the ordinance to use reclaimed water for irrigation. The SFWMD continues to work with local governments and utilities in Broward and Miami-Dade counties to explore reuse options.

In the Kissimmee Basin and Lower West Coast Regions, supplemental sources are being investigated and developed to supplement reclaimed water flows. Several utilities in these regions have wait lists for reclaimed water. Conservation of reclaimed water is also being explored in these regions.

Encourage Reclaimed Water Conservation

In parts of the District where reuse has been practiced for many years, conservation of reclaimed water needs to be promoted to stretch limited supplies of reclaimed water to additional users. Most reclaimed water utilities in Florida currently charge a flat monthly fee for reclaimed water service. This is because many systems began implementing reuse at a time when it was important to have the use of reclaimed water be more attractive to the customer than the use of potable water or groundwater for irrigation, to encourage growth of the customer base. In addition, there was generally a much greater volume of reclaimed water available than the customer base could support and overuse was not discouraged.

As a reuse system with this type of rate structure matures, shortages of reclaimed water become prevalent. The recent drought exacerbated this situation and shortages of reclaimed water became even more prevalent in mature reuse systems. Many systems sought approval for supplemental water supplies from the DEP and the water management districts. Observations made in the Southwest Florida Water Management District (SWFWMD) indicate that, before efficiency standards were implemented, when a customer switches from potable water to reclaimed water for irrigation, the volume used for irrigation is as much as four times greater than that observed for potable water. This is due to the cost differential between the two sources, and the fact that there is often no additional cost to the customer for using greater amounts. Overwatering carries any fertilizers, pesticides and herbicides offsite and results in more frequent applications of these materials.

Installation of meters and implementation of volume-based rate structure is one way to curtail excessive use of reclaimed water. Studies done by the SWFWMD (SWFWMD, 2002a) have concluded that simply providing meters can reduce the use of reclaimed water by residential customers by about 50 percent. Utilities implementing metering will incur increased costs associated with the purchase of the meters and for routine reading of the meters. Of course, these costs may be passed on to the utility's customers as part of their rates for reclaimed water service.

A volume-based rate structure assesses a charge for the water in proportion to the amount of water used. Since customers are billed for reclaimed water actually used, volume-based rates discourage overuse and waste of this water resource. Metering of reclaimed water use is necessary to implement volume-based reclaimed water rates. The SWFWMD investigated information on 14 reclaimed water systems in the Tampa Bay

Area to determine the average amount reclaimed water used by single-family residential irrigation customers. The data reveal that metered single-family residential customers use an average of 534 gallons per day of reclaimed water. The average amount of reclaimed water used by unmetered flat rate single-family residential customers was 980 gallons per day, or almost double the amount of comparable metered customers. The data also reveal that amount of potable quality water offset by both the metered and the unmetered was approximately 300 gallons per day (GPD); therefore, the metered customers are approximately 56 percent efficient (based on potable quality water offset), while the unmetered flat rate customers are only 30 percent efficient (SWFWMD, 2002b). The experience of reuse systems with unmetered flat rate customers is that systems can be severely limited in developing their customer base to its full potential, due to overuse of the reclaimed water by flat rate customers.

Reclaimed Water Estimated Costs

The costs associated with implementation of a reuse program vary depending on the size of the reclamation facility, the facility equipment needed, the extent of the reclaimed water transmission system and the regulatory requirements. Some of the major costs to implement a public access reuse system include the following:

- Advanced secondary treatment
- Reclaimed water transmission system
- Storage facilities
- Alternate disposal
- Application area modifications

Cost savings include negating the need for, or reducing the use of, alternative disposal systems, negating the need for an alternate water supply by the end user and reduction in fertilization costs for the end user. Costs of several items listed above are contained in this chapter and **Chapter 5** of this document.

Seawater

This option involves using seawater from the Atlantic Ocean or Gulf of Mexico as a raw water source. From a quantity perspective, seawater appears to be an unlimited source of water. However, removal of the salts is required before seawater could be used for potable or irrigation purposes. Seawater averages about 3.5 percent dissolved salts, most of which is sodium chloride, with lesser amounts of magnesium and calcium. A desalination treatment technology would have to be used, such as distillation, reverse osmosis or electrodialysis reversal (EDR). As with all surface waters, seawater is also vulnerable to discharges or spills of pollutants that can affect a water treatment system.

Seawater Estimated Costs

The cost of desalination of seawater can be significant, several times the cost of desalination of brackish groundwater due to higher salt content, intake facilities and concentrate disposal. The higher salt content reduces the efficiency of the treatment facility (less gallons of potable water are produced from water pumped) and results in increased concentrate/reject water disposal needs compared to desalination of the brackish groundwater. Cost information from seawater desalination studies show that costs can be significant for seawater desalination. For example, in Singapore, a 36-MGD desalination plant was estimated to cost between $7.52 and $8.77 per thousand gallons.

One way to reduce the cost of seawater desalination is to co-locate the desalination facility with power generating facilities that use seawater for cooling. There are many benefits of co-located desalination facilities and electric power plants. One benefit and cost reduction is the sharing of facility components. There is cost savings associated with using the existing intake and discharge structures of the power plant to provide raw water to the desalination plant and to provide a means for concentrate disposal. It is possible to dispose of the desalination process concentrate by blending it with the power plant's cooling water discharge. Another significant advantage of using power plant cooling water as a source is the temperature of the water is elevated, which reduces the pressure and associated energy necessary to produce the product water.

As stated above, seawater desalination has proven to be economically feasible when co-located with other facilities, such as power plants. Tampa Bay Water recently completed construction of a seawater desalination (RO) treatment facility initially capable of producing 25 MGD of drinking water. The wholesale cost for the desalinated water over the next 30 years is projected to average $2.49 per thousand gallons. The 25-MGD facility cost $110 million and began producing water in March 2003 (Tampa Bay Water, 2003).

When considering costs for using seawater, the proximity to a major potable water transmission system or network has to be considered. Depending on its location, it could be a considerable distance from the seawater treatment facility to a major transmission main to get the treated water into the distribution system. In most areas of the SFWMD, these coastal areas are very urbanized.

Storage

Storage is becoming critical to meeting future water needs. With 60 to 75 percent of the 50 plus inches of average rainfall falling during the rainy season, storage is required to keep this water in the system instead of discharge to tide. Three major types of potential storage options are aquifer storage and recovery, regional and local retention and reservoirs.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is the underground storage of injected water into an acceptable aquifer (typically the FAS in south Florida) during times when water is available, and the later recovery of this water during high demand periods. In other words, the aquifer acts as an underground reservoir for the injected water, reducing water loss to evaporation. Current regulations require injected water to meet drinking water standards when the receiving aquifer is classified as an Underground Source of Drinking Water (USDW) aquifer, unless an aquifer exemption is obtained from the U.S. Environmental Protection Agency (USEPA). Obtaining an aquifer exemption is a rigorous process and few have been approved. However, the USEPA has indicated that a flexible assessment approach will be applied for systems that meet all drinking water standards except fecal coliform.

The volume of water that could be made available through ASR wells depends upon several local factors, such as well yield, water availability, variability in water supply and variability in demand. Due to insufficient data, it is not feasible at this time to estimate the water that could be available through ASR. Typical storage volumes for individual wells range from 10 to 500 million gallons or 31 to 1,535 acre-feet (Pyne, 1995). Where appropriate, multiple ASR wells could be operated as a wellfield, with the capacity determined from the recharge and/or recovery periods. There are potentially many different applications of ASR; however, all store sufficient volumes (adequate volumes to meet the desired need) during times when water is available and recover it from the same well(s) when needed. The storage time is usually seasonal, but can also be diurnal, long-term or for emergencies. The volume of water that could be made available by any specific user must be determined through the District's Consumptive Use Permitting (CUP) Program.

In 2002, there were five ASR wells in the District with an operations permit using treated drinking water or partially treated surface water. There were 15 ASR wells under operational testing, and over 10 wells under construction. In addition to these utility uses, the District, in cooperation with the U.S. Army Corps of Engineers (USACE), is pursuing regional ASR systems as part of the Comprehensive Everglades Restoration Plan. Almost 400 ASR wells are planned around Lake Okeechobee and other significant sources of water, such as major canals.

Treated Water ASR

Treated water ASR involves using potable water as the injection water. Since potable water meets the drinking water standards, this type of ASR application is more easily permitted. There are many examples in Florida of utilities using treated water ASR including several in the SFWMD. These include Collier County, Lee County and the City of Boynton Beach utilities.

Raw Water or Partially Treated ASR

Raw water or partially treated ASR involves using groundwater from freshwater aquifers or surface water. Some treatment may be necessary prior to injection to meet the appropriate standards. Raw water or partially treated ASR is usually discussed in combination with surface water storage, such as a reservoir or canal system. The reservoir or canal system would capture excess surface water and provide sufficient volumes of water for the ASR injection cycle. In lieu of withdrawing surface water directly from a surface water body, potential projects may involve installation of vertical and/or horizontal wells, and use of the soil matrix between the water body and well intake for filtration, sometimes referred to as bank filtration. This type of ASR could be used as a source of water for potable needs, a supplemental source to reclaimed water or for environmental purposes.

Reclaimed Water ASR

Reclaimed water ASR involves using reclaimed water as the injection water. Several communities in Florida are interested in reclaimed water ASR and are investigating the feasibility of such a system. In 2002, two utilities in the SWFWMD initiated operational testing of ASR systems using reclaimed water. Some modification to treatment systems or installations of additional treatment components may be necessary to meet applicable standards.

Aquifer Storage and Recovery Estimated Costs

Estimated costs for an ASR system depend on the type of the ASR system. Estimated costs for 2 MGD potable water ASR system and a 5-MGD surface water ASR system are provided in **Table 10**. For a 2-MGD drinking water ASR system, the total construction cost is estimated at $990,000 and an annual operations and maintenance cost of $83,300. This equates to a cost of about $0.44 per thousand gallons. For a 5-MGD surface water ASR system, the total construction cost is estimated at $6.54 million and an annual operations and maintenance cost of $364,781.This equates to a cost of about $1.05 per thousand gallons.

Table 10. Aquifer Storage and Recovery Estimates.

Plant Capacity (MGD)	Construction Cost	Non-Construction Costs	Land Cost & Acquisition	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
Potable Water ASR						
2	$825,000	$165,000	$0	$55,000	$83,300	$0.44
Surface Water ASR						
5	$5,450,000	$1,090,000	$0	$290,000	$364,781	$1.05

Source: Email from Peter Kwiatkowski, Lead Hydrogeologist, SFWMD, February 28, 2003.

The potable water cost information assumes the ASR well will be located at the water treatment plant site and have a 70 percent recovery rate. The surface water ASR cost information assumes the ASR facilities will be located at a remote site, microfiltration treatment of the water being injected, and a 70 percent recovery rate. Detailed cost information is located in the appendices of each regional water supply plan.

Drainage Wells – Kissimmee Basin

Drainage wells are injection wells and are regulated under the same guidelines as ASR wells; however, the function and costs associated with these wells are different. Like ASR wells, a drainage well's function is to store surface water that is captured in the underground aquifer system. Unlike ASR wells, however, there is no extraction operation associated with these wells. The advantage of the storage function is to recharge the aquifer, benefiting multiple well.

The metro-Orlando area is the only location in the District where drainage wells exist. An estimated 350 to 400 wells are known. The majority of these wells were installed about 40 years ago to assist in controlling lake levels. The wells generally receive storm water discharged to lakes, but there are wells that take water directly from street runoff. The potential for contamination to the aquifer system is of concern with these wells. It is estimated that as much as 20 inches a year of recharge may be due to drainage wells in the Orlando area.

The costs associated with drainage wells are similar to those of normal production wells, with the exception that there are no energy costs. The permitting of these wells is similar to that of ASR wells and requires approval from the FDEP. Recently, however, the potential water quality problems associated with these wells have escalated. Thus, the number of drainage wells permitted has dropped dramatically. Consideration of this option would include a lengthy permitting effort to document risks associated with direct injection to the freshwater aquifer.

Regional and Local Retention

Regional and local retention is an opportunity to increase water storage in watersheds through the manipulation and modification of the drainage system that serves that area, while still maintaining an appropriate level of flood protection. As described earlier in this document, much of the region was drained to support agricultural and urban development. This has resulted in lowered groundwater tables that may affect natural systems, as well as water availability in these areas. In some areas of the SFWMD, increased water retention in canal systems has increased groundwater levels, thereby reducing the frequency of irrigation.

This water supply option includes structural and operational changes that allow capturing of additional runoff water to be held in the secondary canal systems. A portion of the water captured in the secondary canal systems will come from excess water in the primary canal system, in addition to water captured within the secondary system itself. This option will also foster the utilization of this water by allowing appropriate reductions in water levels before water is obtained from regional sources to replenish water in the secondary canal systems. One benefit of this option is to stabilize the salt front by holding higher surface and groundwater levels in coastal areas, thereby minimizing saltwater intrusion. Higher groundwater levels should also help to recharge wellfields and decrease the impact of water shortages. Modifying secondary canal operations will improve local water use and recharge, and will help to reduce the need to bring water in from regional sources. When considering higher water levels, the potential impacts on flood protection must also be addressed.

Reservoir

This option involves the capture and storage of excess surface water during rainy periods and subsequent release during drier periods for environmental and human uses. The capture of excess surface water runoff and groundwater seepage from canals and rivers, and storage of these waters in existing or new surface water reservoirs or impoundments, provides an opportunity to increase the supply of fresh water during dry periods. The primary problems associated with surface water storage are the expense of constructing and operating large capacity pumping facilities, the cost of land acquisition, appropriate treatment costs, the availability of suitable locations, seepage losses and the high evaporation rates of surface water bodies.

Costs associated with surface water storage vary depending on site-specific conditions of each reservoir. A site located near an existing waterway will increase the flexibility of design and management and reduce costs associated with water transmission infrastructure. Another factor related to cost would be the existing elevation of the site. Lower site elevations would allow for maximum storage for the facility, while reducing costs associated with water transmission and construction excavation. The depth of the reservoir will have a large impact on the costs associated with construction; deeper reservoirs result in higher levee elevations, which can significantly increase construction costs.

Costs associated with two types of reservoirs are depicted in **Table 11**. The first is a minor facility with pumping inflow structures and levees designed to handle a maximum water depth of 4 feet. It also has internal levees and infrastructure to control internal flows and discharges. The second type shown below is a major facility with similar infrastructure as the minor facility. However, the water design depths for this facility range from 10 to 12 feet. Costs increase significantly for construction of higher levees, but these costs can be somewhat offset by reduced land requirements. Increased land cost could significantly increase cost.

Table 11. Surface Water Storage Costs.

Reservoir Type		COST			
		Construction $/Acre-feet	Engineering $/Acre-feet	Construction Management $/Acre-feet	Land $/Acre
Minor Reservoir/STA	Range	424–6,612	78–1,074	30–786	3,666–24,690
	Average	2,799	470	393	13,295
Major Reservoir	Range	421–4,223	29–565	63–745	2,702–32,533
	Average	1,671	140	292	14,188

Note: All costs were obtained from the latest "Master Implementation Sequencing (MISP) Plan Version 1.0" or the MISP developed as part of the P3E schedule of the CERP Project Implementation Reports.

Surface Water

This option involves the use of surface water as a supply source. Surface water bodies that could be used for water supply include lakes, rivers and canals. Several potential sources of surface water have been identified in each planning area that could be considered to meet future demands. Most of these potential sources convey water from inland areas and discharge to estuarine systems along the coast, or in the Kissimmee, to Lake Okeechobee. The volume of surface water that could be considered available from these sources for human uses would be the volume over what is needed for environmental purposes. Water would usually be available during the wet season from these sources, but limited during the dry season. Minimum flows and levels have been established for some water bodies that have to be considered when determining water availability from surface water. Likewise, water reservations (see Chapter 4) must be considered when determining surface water availability.

Surface Water Estimated Costs

Estimates of costs for the installation of these facilities are provided in **Table 12**. For the purposes of the estimate, a pump rated at 60,000 GPM is assumed.

Table 12. Pump Installation and Operating Costs.

Pump Type	Engineering/ Design Cost	Construction Costs	Operation and Maintenance Cost
Electric	$50,000	3-4 million[a]	$60/hr
Diesel	$50,000	$1.5-3 million	$40/hr

a. Does not include cost of installing electrical power to site.

Stormwater Reuse

Stormwater reuse is defined as the collection of stormwater runoff from urban areas and should be distinguished from runoff collection from agricultural land, which is addressed under surface water storage. The stormwater use option is thought to be most applicable to landscape irrigation practices on a localized scale. A common application of stormwater use is the use of man-made lakes to supplement golf course irrigation demands and residential landscaping. The costs associated with these types of uses are considered to be nominally above those for the groundwater alternative that it would replace.

Utility Interconnections

Interconnection of treated and/or raw water distribution systems is an option typically limited for the purposes of providing backup water service in the event of disruption of a water service. This operation, although currently employed by many utilities, is thought of a means to address local or temporary service shortfalls. Regional implementation of a utility interconnection system could be employed as a supply management tool. The purpose of implementing this alternative would be to shift withdrawals from areas deemed to be at highest risk for adverse impacts to areas where the withdrawals are projected to have less impact. This would be completed through bulk purchase of raw or treated water from neighboring utilities in lieu of expanding an existing withdrawal and/or treatment plant.

A detailed study of distribution systems proposed for interconnection would need to be conducted to address system pressures, physical layout of the supply mains, impacts on fire flows and compatibility of the waters, among other items. Most existing water distribution systems are constructed with the smallest diameter pipes (low volume) at its extremities. As a result, utility interconnects for the purposes of bulk transfers of water could be more than connecting two distribution systems. It will require extension of larger water mains within the service area to extremities, connecting to similar pipes in the adjoining service area.

Utility Interconnection Estimated Costs

The costs associated with public water system interconnects are difficult to estimate and could vary greatly depending on the size, distance and potential engineering challenges. Typically, an interconnect system includes transmission mains, valves, jack and bores, encasements and tunneling. Transmission mains are primarily made from ductile iron pipe and prestressed concrete cylinder pipe, typically varying in size from 12 to 60 inches in diameter.

The cost of transmission mains is provided in **Table 13**. Cost varies with diameter and length of the transmission main. These costs do not include the cost of land and right-of-way requirements or the cost of jack and bores, valves and other appurtenances. **Table 14** presents the combined costs of transmission mains, valves and jack and bores. The combined costs assume valves would be installed approximately every mile along the pipeline and jack and bores would occur approximately every 5 miles.

Table 13. Transmission Main Cost.

Pipe Size (in-dia)	Construction Costs ($/ft)	Non-Construction Costs ($/ft)	Total ($/ft)
12	$39	$18	$57
16	$55	$25	$80
20	$71	$32	$102
24	$87	$39	$126
30	$110	$49	$159
36	$134	$60	$194
42	$158	$71	$228
48	$203	$91	$294
54	$241	$108	$349
60	$277	$125	$402

Source: St. Johns River Water Management District, 1997 Updated with Projected 2005 Construction Cost Index.

Table 14. Total Transmission Main Cost.

Pipe Size (in-dia)	Construction Costs ($/ft)	Non-Construction Costs ($/ft)	Total ($/ft)
12	$42	$19	$60
16	$58	$26	$84
20	$77	$35	$111
24	$95	$43	$137
30	$121	$54	$175
36	$149	$67	$216
42	$175	$79	$254
48	$224	$101	$325
54	$266	$120	$385
60	$307	$138	$446

Source: St. Johns River Water Management District, 1997 Updated with Projected 2005 Construction Cost Index.

CHAPTER 4
Water Supply Regulation

The water management districts receive their authority to regulate water resource related activities pursuant to Chapter 373, F.S. The primary regulatory tools related to water supply and uses of water are contained in Part II of Chapter 373. These tools are consumptive use permits, water reservations, minimum flows and levels and water shortage restrictions. These tools are summarized below.

CONSUMPTIVE USE PERMITTING

Consumptive use permits are issued by the water management districts pursuant to Part II of Chapter 373, F.S.:

> Subsection 373.217(2), F.S. It is the further intent of the Legislature that Part II of the Florida Water Resources Act of 1972, as amended, as set forth in ss. 373.203-373.249, shall provide the exclusive authority for requiring permits for the consumptive use of water and for authorizing transportation thereof pursuant to s. 373.223(2).

The legislation has expressly repealed any other provision, limitation or restriction of the state, any political subdivision or municipality dealing with the regulation of the consumptive use of water, with the exception of the *Florida Electrical Power Plant Siting Act*. (Section 373.217, F.S., *et seq*.)

All water withdrawals within the SFWMD require a District water use permit except: 1) water used in a single family dwelling or duplex, provided that the water is obtained from one well for each single family dwelling or duplex, used either for domestic purposes or outdoor uses; 2) water used for fire fighting; and 3) the use of reclaimed water. The first exemption is provided in state legislation; the latter two are District exemptions.

In order to obtain a consumptive use permit, the permit applicant must provide reasonable assurances that the use is "reasonable-beneficial," will not interfere with any presently existing legal use of water, and is consistent with the public interest, pursuant to Section 373.223, F.S.

> Section 373.019(13), F.S. "Reasonable-beneficial use" means the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest.

The SFWMD implements this test pursuant to rules adopted in Chapter 40E-2 and Chapter 40E-20, F.A.C. Permits are conditioned to assure that uses are consistent with the overall objectives of Chapter 373, F.S. and are not harmful to the water resources of the area, under Section 373.219, F.S. Conditions for issuance of a consumptive use permit address several issues including saltwater intrusion, wetland protection, pollution, impacts to offsite land uses, use of reclaimed water, interference with existing legal uses and minimum flows and levels. In addition, the rules require consideration of relevant portions of the State Water Resource Implementation Rule (Chapter 62-40, F.A.C.) adopted by the Department of Environmental Protection as part of the reasonable-beneficial use test.

The Basis of Review is incorporated by reference into Chapters 40E-2 and 40E-20, F.A.C. The objective of the Basis of Review is to specify the general procedures and information used by District staff for review of water use permit applications. All criteria in the Basis of Review apply to processing individual permit applications, and specified criteria apply to processing of general permit notices of intent.

In addition Chapter 40E-5, F.A.C. implements Section 373.106, F.S., which authorizes the District to issue permits for projects involving artificial recharge or the intentional introduction of water into any underground formation, except activities under Chapter 377, F.S. Projects that inject waters into aquifers that contain a total dissolved solids concentration greater than 10,000 mg/L or for the purpose of disposal are not regulated under this chapter.

In its 2003 rulemaking effort, the SFWMD significantly amended Chapters 40E-2, 40E-20 and 40E-5, F.A.C. and the Basis of Review. These rule changes went into effect September 1, 2003.

In addition, procedures for processing water use permit applications are set forth in Rules 40E-1.603 and 40E-1.606. Rule 40E-1.610 provides procedures for permit renewals and Rule 40E-1.6107 sets forth procedures for permit transfers.

Under Florida law, a consumptive use permit provides the permittee with the right to use water consistent with the conditions of the permit for the duration of the permit. Prior to permit expiration, the permittee must obtain a renewal of the permit in order to continue the water use. Water is consumed for many purposes including agricultural, landscape and golf course irrigation; public water supply; commercial; and industrial uses. The District rules classify permits into these separate use classifications.

Existing legal uses of water must meet the conditions for issuance of a permit during a 1-in-10 year drought condition, known as the "level-of-certainty." "Level of Certainty" is a concept that provides certainty for the user that given a specific drought event (up to a 1-in-10 year drought event), water will be available from the source. Certainty also means that the water resource, from which the water is withdrawn, will be evaluated to assure that no harm will occur during this drought event. The result is not a guarantee that droughts will not occur, but rather that legal users of the natural environment will have known that during normal climatic times, water will be available and the resource protected from harm. The level-of-certainty planning criteria have been incorporated into the consumptive water use process for many years, but only recently added to the statute. The level of certainty planning goal established by the legislature is the 1-in-10 year drought event provided in Paragraph 373.0361(2)(a)1, F.S.

The SFWMD's irrigation permit basin expiration dates have been adjusted to stagger the permits within the four areas of the District in order to ensure that the appropriate rules are in place to implement the applicable regional water supply plans and to ensure that the permits can be processed for renewal in an integrated cumulative manner. Specific basin expiration dates are set forth in the Basis of Review. If the basin boundaries overlap, the District will assign a basin that best reflects the resource issues. For those permits with split basins, the rule provides that a request may be made for the permit application to be reviewed concurrently with other water use applications in the same irrigation permit basin. Applications for permit renewals are to be made six months prior to the basin expiration dates.

Pursuant to Section 373.233, F.S., applications are considered to be competing when the proposed use of water by two or more applicants will exceed the amount of water that is available for consumptive use due to water resource availability or are in conflict.

RESERVATIONS

As required by state and federal law, reservations of water for the natural system will be established by the SFWMD pursuant to state law. The state law on water reservations, in the Florida Statutes provides:

Subsection 373.223(4), F.S., The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.

In simple terms, when water is reserved under this statute, it is not available to be allocated for use under a consumptive use permit. The SFWMD anticipates that both CERP and non-CERP related reservations would be adopted for the Everglades restoration. Specific information regarding establishment of reservations for a given planning area can be found in the applicable regional water supply plan.

Existing allocations under a consumptive use permit are protected to the extent they are "not contrary to the public interest." Under Florida law, permitted uses and domestic water uses (which are exempt from requirements to obtain a permit) have the legal status of an "existing legal use."

To date no water reservations have been adopted by the SFWMD. However, over the next several years initial reservations and the CERP related reservations will be adopted.

MINIMUM FLOWS AND LEVELS

The SFWMD is responsible for the implementation of statutory provisions in Section 373.042, F.S., requiring establishment of Minimum Flows and Levels (MFLs) for watercourses and aquifers. Generally stated, the MFLs for a given watercourse or aquifer are the limit at which further withdrawals would be significantly harmful to the water resources of the area provided in Section 373.042, F.S. Significant harm is the temporary loss of water resource functions, which result from a change in surface or groundwater hydrology, which takes more then two years to recover, as set forth in Rule 40-E8.021(28), F.A.C. Certain exclusions and considerations for establishing MFLs, including defining “significant harm” for a specific water body, are contained in Section 373.0421, F.S. Recovery and prevention strategies must be developed if there are existing or projected shortfalls in meeting the MFL, as provided in Section 373.0421, F.S.

Minimum flow and level standards for specific water bodies and aquifers within the SFWMD are contained in Chapter 40E-8, F.A.C., which also includes recovery and prevention strategies for each MFL. At this time MFLs have been established for Lake Okeechobee, the Everglades (Water Conservation Areas, Everglades National Park and Rotenberger and Holey Land Wildlife Management Areas), the northern Biscayne Aquifer within the Lower East Coast, the Lower West Coast confined aquifers, the Caloosahatchee River, the Northwest Fork of the Loxahatchee River and the St. Lucie River.

Annually SFWMD updates its Priority Water Body List, which states the water bodies and schedules for establishing MFLs, pursuant to Section 373.042, F.S. Further information regarding specific MFL can be found in the applicable regional water supply plans, including recovery and prevention strategies for each MFL water body.

In addition to the standards and recovery and prevention strategies, specific consumptive use permitting criteria for MFLs are adopted in Chapter 40E-2, F.A.C. and water shortage criteria for specific MFL regions, if necessary are adopted in Chapters 40E-21 and 40E-22, F.A.C.

The consumptive use permitting (CUP) rules require as a condition for permit issuance that an applicant provide reasonable assurances the use of water will meet established minimum flows and levels and implementation provisions provided in Rule 40E-2.301(1)(i), F.A.C. A requirement that the use be consistent with the applicable recovery or prevention strategy is the basic premise underlying these rules. The MFL implementation rule for CUP in Section 3.9.1 of the Basis of Review has separate criteria for requests for permit renewals and requests for new or modified permits. Two categories of impact criteria are also identified for direct withdrawals from the MFL water body and for indirect withdrawals from a MFL water body. Direct withdrawals are those that directly pump from a MFL water body, or cause more than a 0.1 foot of drawdown from the groundwater source under the MFL water body. Indirect withdrawals are those that indirectly influence water levels or flows within the MFL water body. This provides a link to the applicable regional water supply plan where the MFL water body is located and the associated water resource development projects designed to help recover to or prevent violation of the MFL provided in Rule 40E-8.021(6)(9) F.A.C.

WATER SHORTAGE PLAN

Pursuant to Section 373.246, F.S., water shortage declarations are designed to prevent serious harm from occurring to water resources. Serious harm is defined by SFWMD rule as long-term, irreversible or permanent impacts to the water resource provided in Rule 40E-8.021(27), F.A.C. Declarations of water shortages by the governing board are used as a tool to assist in preventing serious harm to the water resources during droughts, while equitably distributing water resources for consumptive and nonconsumptive uses, as provided in Chapter 40E-21, F.A.C. Water shortage declarations are imposed in phases, increasing water use cutbacks as drought conditions increase.

The Water Shortage Plan (Sections 373.175 and 373.246, F.S.) is linked to MFL implementation pursuant to Chapter 40E-8, F.A.C. Water shortage cutbacks are not intended to be implemented as a recovery plan for meeting a MFL, rather are for drought management purposes, as provided in Rule 40E-8.441, F.A.C. For drought conditions greater than a 1-in-10 year event, it may be necessary to decrease water withdrawals to help prevent water levels from declining to and below a level where significant harm to the resource could potentially occur. Minimum flows and levels are considered as a factor in triggering intermediate phases of water shortage cutbacks. Water shortage triggers are water levels at which phased restrictions will be declared under the SFWMD's Water Shortage Program. Other considerations are set forth in Rule 40E-8.441(4), F.A.C. and Chapter 40E-21, F.A.C.

RESOURCE PROTECTION CHART

Harm, Serious Harm and Significant Harm Standards are defined as follows (**Figure 6**):

> Rule 40E-8.021(8) F.A.C. *Harm* – means the temporary loss of water resource functions, as defined for consumptive use permitting in Chapter 40E-2, F.A.C., that results from a change in surface or ground water hydrology and takes a period of one to two years of average rainfall conditions to recover.
>
> Rule 40-E8.021(28), F.A.C. *Significant Harm* – means the temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm. The specific water resource functions addressed by a MFL and the duration of the recovery period associated with significant harm are defined for each priority water body based on the MFL technical support document.
>
> Rule 40-E8.021(27), F.A.C. *Serious Harm* – means the long-term loss of water resource functions, as addressed in Chapters 40E-21 and 40E-22, F.A.C., resulting from a change in surface or ground water hydrology.

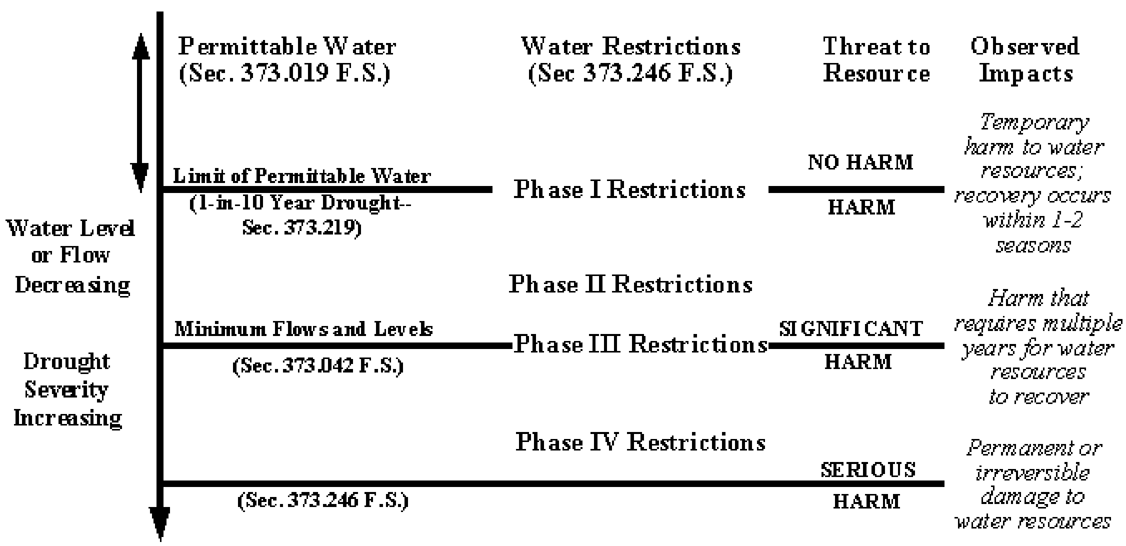


Figure 6. Conceptual Relationship Among the Harm, Serious Harm and Significant Harm Standards.

CHAPTER 5
Water Quality and Treatment

There are water quality standards that must be met for different types of uses. These standards are generally based on health or water use technology requirements; water frequently needs treatment in order to meet these standards.

Technology can also be employed to augment and make the most of available water resources. Human activities, such as waste disposal or pollution spillage, have the potential of degrading ground and surface water quality.

WATER QUALITY STANDARDS

Drinking Water Standards

There are two types of drinking water standards, primary and secondary. Both of these standards are the maximum contaminant levels (MCL) for public drinking water systems. Primary drinking water standards include contaminants that can pose health hazards when present in excess of the MCL. Secondary drinking water standards, commonly referred to as aesthetic standards, are those parameters that may impart an objectionable appearance, odor or taste to water, but are not necessarily health hazards. Current MCLs for drinking water in Florida are available from: http://www.floridadep.org.

Nonpotable Water Standards

Water for potable and nonpotable water uses have different water quality requirements and treatability constraints. Nonpotable water sources include surface water, groundwater and reclaimed water. Unlike potable water, with very specific quality standards to protect human health, water quality limits for nonpotable uses are quite variable and are dictated by the intended use of the water. For example, high iron content is usually not a factor in water used for flood irrigation of food crops, but requires removal for irrigation of ornamentals crops. Excessive iron must also be removed for use in microirrigation systems, which become clogged by iron precipitate.

Nonpotable water uses include agricultural, landscape, golf course and recreational irrigation. This water may also be acceptable for some industrial and commercial uses. For an irrigation water source to be considered for a specific use, there must be sufficient quantities of that water, at a quality compatible with the crop it is to irrigate. Agricultural irrigation uses require that the salinity of the water not be so high as to damage crops either by direct application or through salt buildup in the soil profile. In addition, constituents, such as iron or calcium, which can damage the irrigation system infrastructure or equipment, must be absent or economically removable. Landscape, golf course or recreational irrigation water often have additional aesthetic requirements, such as color and odor.

In addition to water quality considerations associated with the intended use of nonpotable water, reclaimed water is subject to wastewater treatment standards ensuring the safety of its use. As with any irrigation water, reclaimed water may contain some constituents at concentrations that are not desirable. Problems that might be associated with reclaimed water are only of concern if they hinder the use of the water or require special management techniques to allow its use. A meaningful assessment of irrigation water quality, regardless of source, should consider local factors, such as specific chemical properties, irrigated crops, climate and irrigation practices (WSTB, 1996).

GROUNDWATER CONTAMINATION AND IMPACTS TO WATER SUPPLY

Groundwater Contamination Sources

The Surficial Aquifer System (SAS) is easily contaminated by activities occurring at the surface of the land. Once a contaminant enters the aquifer, it may be difficult to remove. In many cases, leaks, spills or discharges of contaminants spread over long periods, resulting in contamination of large areas of the aquifer. The preferred method of addressing the issue of water supply contamination, therefore, is to prevent contamination of the aquifer, and protect public water supply wells and wellfields from activities that present a possible contamination threat. Saltwater intrusion also presents a potential threat to aquifers in the regional planning areas.

Solid Waste Sites

Many of the older landfills and dumps were used for years with little or no control over what materials were disposed in them. Although most have not been active for some time, they may still be a potential threat to the groundwater resource. Groundwater monitoring began in the early 1980s for all the landfills.

Contaminants from landfills are leachates. Leachates often contain high concentrations of nitrogen and ammonia compounds, iron, sodium, sulfate, total organic carbon (TOC), biological oxygen demand (BOD) and chemical oxygen demand (COD). Less common constituents, which may also be present, include metals, such as lead or chromium and volatile or synthetic organic compounds associated with industrial solvents, such as trichloroethylene, tetrachloroethylene and benzene. The presence and concentration of these constituents in the groundwater are dependent upon several factors that dictate the extent and character of the resulting groundwater impacts, including:

- Landfill size and age.
- Types and quantities of wastes produced in the area.
- Local hydrogeology.
- Landfill design/landfilling techniques.

An effective groundwater monitoring program is crucial for accurate determination of groundwater degradation. Improperly located monitoring wells can result in the oversight of a contaminant plume, or certain parameters may not be observed in the groundwater for many years, depending upon soil adsorption capacities and groundwater gradient.

Hazardous Waste Sites

The FDEP Waste Management Division sponsors several programs that provide support for hazardous waste site cleanup. Not all the potential hazardous waste sites actually contain contamination. The potential hazardous waste sites include locations in the Early Detection Incentive Program, the Petroleum Liability and Restoration Program, the Abandoned Tank Restoration Program, the Petroleum Cleanup Participation Program, the Preapproved Advanced Cleanup Program and other programs. Locations and cleanup status can be obtained through the FDEP Waste Management Division. Current listings of hazardous waste sites are available from: http://www.floridadep.org.

Superfund Program Sites

The *Comprehensive Environmental Response, Compensation and Liability Act of 1980*, commonly known as "Superfund," authorized the U.S. Environmental Protection Agency (USEPA) to identify and remediate uncontrolled or abandoned hazardous waste sites. The National Priorities List targets sites considered to have a high health and environmental risk. The USEPA has a web site with more information on the Superfund Program available from: http://www.epa.gov.

Petroleum Contaminant Sites

Sites are reported to the FDEP if contamination has been noticed in the soil, surface water, groundwater or monitoring wells. For more information on the Petroleum Clean-up Program, please refer to the FDEP's web site available from: http://www.floridadep.org.

Septic Tanks

Septic systems are a common method of on-site waste disposal. There are numerous septic tanks in the regional planning areas. Septic tanks may threaten groundwater resources used as drinking water sources.

Saltwater Intrusion

Saltwater intrusion along the coast of the planning regions has been advanced by canal excavation and aquifer development for public water supplies and agriculture. In some canals, salinity control structures have been installed to limit saltwater encroachment by maintaining freshwater heads on the inland side. The greatest threat from saltwater intrusion lies where groundwater and surface water gradients are lowest.

The SFWMD maintains a saltwater intrusion database that collects information on chloride, specific conductance and water levels from the District's monitoring network. The monitoring network consists of data supplied from monitoring wells by the public water supply utilities and the U.S. Geologic Survey (USGS).

In addition to saltwater intrusion from coastal waters, overdevelopment of aquifers overlying aquifers that are more saline increases the possibility of upconing and contamination from the poorer quality layers. This potential exists throughout the regional planning areas. Although upconing of saline water is not considered true seawater intrusion, it is a significant threat because of its potential to degrade potable water supplies.

Cross contamination of shallow aquifers has also occurred from many of the Floridan Aquifer System (FAS) wells in the regional planning areas. Numerous artesian wells were drilled into the FAS (central Okeechobee County and south) for agricultural water supply and oil exploration from the 1930s through the 1950s. Many of these wells were short-cased, meaning the casings extended to less than about 200 feet below land surface (bls), which exposed the shallower zones to invasion by the more saline Floridan water. Additionally, steel casings may have corroded, allowing inter-aquifer exchange through the casings. Often, if a well was abandoned, it was plugged improperly or simply left open, free flowing on the land surface, and recharging the Surficial Aquifer System (SAS) with saline water. The result is the existence of localized sites throughout the shallow aquifers containing anomalously high concentrations of dissolved minerals.

In 1981, the Florida Legislature passed the *Water Quality Assurance Act*, which required the water management districts to plug abandoned FAS wells. Under this program, hundreds of known abandoned wells, including most of the known free-flowing wells, were plugged. Floridan wells are required by statute to be equipped with a valve capable of controlling the discharge from the well. These wells are the responsibility of the property owners where the well is located.

Another source of localized pockets of mineralized water is connate water, theorized to be ancient seawater remaining from periods of inundation, entrapped within the aquifer and relatively unexposed to freshwater flushing.

The effects of seawater intrusion, upconing, aquifer cross contamination and connate water can create a complex and somewhat unpredictable scenario of local groundwater quality. Monitor wells provide a great deal of information where they exist, but there are limits as to how many wells can be installed and monitored. Where more detailed information is required, additional methods may be needed to monitor the saltwater interface. Geophysical surveys can provide extremely useful information about the extent of saltwater intrusion at relatively low cost (Benson and Yuhr, 1993).

Impacts to Water Supply

The costs and difficulty of removing a contaminant by a drinking water treatment plant can be considerable, depending on the material to be removed. Many of the major contamination sources identified can generate contaminants that are not easily treated. For example, nitrate is generated by septic systems or by fertilizer application, benzene from leaking gasoline tanks and volatile organic compounds from various hazardous waste contamination sites.

WATER TREATMENT TECHNOLOGIES

Several water treatment technologies are currently employed by the regional water treatment facilities in the regional planning areas including chlorination, lime softening and membrane processes. The FDEP regulates water treatment plants. Higher levels of treatment may be required to meet increasingly stringent drinking water quality standards. In addition, higher levels of treatment may be needed where lower quality raw water sources are pursued to meet future demand. This section provides an overview of several water treatment technologies and their associated costs.

Costs are presented where cost information was available. Unless noted otherwise, cost information was obtained from the “Water Supply Needs and Sources Assessment: Alternative Water Supply Strategies Investigation, Water Supply and Wastewater Systems Component Cost Information” provided by the St. John’s River Water Management District (SJRWMD, 1997). The information was adjusted to 2005 dollars using a projected 2005 calibration cost index. An explanation of cost terms and relative information is provided in **Chapter 3** under Water Source Options.

Disinfection

Disinfection, the process by which pathogenic microorganisms are destroyed, provides essential public health protection. All potable water requires disinfection as part of the treatment process prior to distribution. These include chlorination, ultraviolet (UV) light and ozone.

Community public water supplies are required to provide adequate disinfection of the finished/treated water and to provide a disinfectant residual in the water distribution system. Disinfectant may be added at several places in the treatment process, but adequate disinfectant residual and contact time must be provided prior to distribution to the consumer.

Chlorination

Chlorine is a common disinfectant used in the United States. The use of free chlorine as a disinfectant often results in the formation of levels of Trihalomethanes (THMs) and other disinfectant by-products (DBP) when free chlorine combines with naturally occurring organic matter in the raw water source. Existing treatment processes are being modified to comply with changing water quality standards. Add-on treatment technologies that are effective at removing these compounds or preventing their formation include ozone disinfection, granular activated carbon (GAC), enhanced coagulation, membrane systems and switching from chlorine to chlorine dioxide (Hoffbuhr, 1998).

The primary disinfectant used within the SFWMD is chlorination or chlorine used with ammonia to form chloramine. The rate of disinfection depends on the concentration and form of available chlorine residual, time of contact, pH, temperature and other factors. Current disinfection practice is based on establishing an amount of chlorine residual during treatment and, then, maintaining an adequate residual to the customer's faucet. Chlorine is also effective at reducing color. Chlorination has widespread use in the United States.

Chlorination Costs

The costs associated with a chlorination system are presented in **Table 15**. The construction costs include equipment and installation, and the operations and maintenance costs include energy, labor, chemical and normal maintenance.

Table 15. Estimated Costs for Chlorination.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$74,423	$33,490	$0	$16,577	$26,763	$0.07
5	$114,719	$51,624	$0	$48,290	$63,991	$0.04
10	$192,033	$86,415	$0	$87,381	$113,664	$0.03
20	$346,500	$155,925	$0	$165,564	$212,988	$0.03

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Ultraviolet Light

The ultraviolet (UV) light disinfection process does not use chemicals. Microorganisms, including bacteria, viruses and algae are inactivated within seconds of UV light disinfection.

Ultraviolet Light Disinfection Process

The UV disinfection process takes place as water flows through an irradiation chamber. Microorganisms in the water are inactivated when the UV light is absorbed. A photochemical effect is created and vital processes are stopped within the cells, thus making the microorganisms harmless. UV light inactivates microbes by damaging their nucleic acid, thereby preventing the microbe from replicating. When a microbe cannot replicate, it is incapable of infecting a host.

UV light is effective in inactivating Cryptosporidium, while at the same time decreasing chlorinated disinfection by-products. One major advantage of UV light disinfection is that it is capable of disinfecting water faster than chlorine, and without the need for retention tanks or potentially harmful chemicals (AWWA, 2003).

Ozonation

Ozonation is a water disinfection method that uses the same kind ozone found in the atmosphere. By adding ozone to the water supply and then sending an electric charge through the water, water suppliers inactivate disease-causing microbes including Giardia and Cryptosporidium. Contact times required for disinfection by ozone are short (seconds to several minutes) when compared to the longer disinfection time required by chlorine. Ozonation is an effective way to alleviate most of a water supply's taste and odor issues (AWWA, 2003).

Ozonation is widely used in Western Europe. In the U.S., ozonation has had limited use by community water suppliers in California, Colorado, Michigan, Maine, New Jersey, Oklahoma, Pennsylvania, Texas, Wisconsin and Wyoming. Because of the massive amount of electricity necessary for treatment, the cost of ozonation is approximately 4 times higher than that of traditional chlorine disinfection. Unlike chlorine, ozone disinfection dissipates quickly in water supplies. Contaminants entering an ozonated water supply after treatment will be unaffected. Ozonation does not produce the disinfection by-products associated with chlorine disinfection.

Aeration

This treatment process is used in areas with high quality raw water, which only needs to be aerated to remove hydrogen sulfide, which causes tastes and odors, or the removal of carbon dioxide, which can reduce the lime demand in lime softening treatment. Aeration also adds oxygen to the water. More recently, aeration has been used to remove trace volatile organic contaminants from water, which are believed to cause adverse health effects.

Aeration Process

In most water treatment aeration process applications, air is brought into contact with water in order to remove a substance from the water, a process referred to as desorption or stripping. This can be accomplished through packed towers, diffused aeration or tray aerators.

A packed tower consists of a cylindrical shell containing packing material. The packing material is usually individual pieces randomly placed into the column. The shapes of the packing material vary and can be made of ceramic, stainless steel or plastic. Water is introduced at the top of the tower and falls down through the tower as air is passing upward.

Diffused aeration consists of bringing air bubbles in contact with a volume of water. Air is compressed and then released at the bottom of the water volume through bubble diffusers. The diffusers distribute the air uniformly through the water cross section and produce the desired air bubble size. Diffused aeration has not found wide spread application in the water treatment field.

Cascading tray aerators depend on surface aeration that takes place as water passes over a series of trays arranged vertically. Water is introduced at the top of a series of trays. Aeration of the water takes place as the water cascades from one tray to the other.

Aeration Costs

The costs associated with an aeration system are presented in **Table 16**. The construction costs include the equipment and installation costs of the aeration unit. These costs do not include the cost of pumping and storage units.

Table 16. Estimated Costs for Aeration.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$93,254	$41,964	$0	$4,561	$17,324	$0.05
5	$354,661	$159,597	$0	$7,205	$55,746	$0.03
10	$503,540	$226,593	$0	$12,837	$81,754	$0.02
20	$641,792	$288,807	$0	$22,528	$110,367	$0.02

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Filtration

Filtration systems are used in water treatment to remove particulate matter from the water supply.

Filtration Costs

The costs associated with a filtration system are presented in **Table 17**.

Table 17. Estimated Costs for Filtration.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$719,382	$323,722	$12,500	$3,493	$102,686	$0.28
5	$1,065,957	$479,681	$25,000	$11,577	$158,938	$0.09
10	$2,364,132	$1,063,859	$40,000	$21,738	$347,656	$0.10
20	$3,800,004	$1,710,002	$78,750	$40,073	$564,789	$0.08

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Coagulation, Flocculation and Sedimentation

Coagulation, flocculation and sedimentation are used to remove suspended material and color. These may be used for pretreatment for other process or technologies, such as reverse osmosis.

Cost estimates for coagulation, flocculation and sedimentation are presented in **Table 18**. The construction costs include treatment components, such as the rapid mix, flocculation basin, sedimentation basin and filters, and the cost associated with the other integral treatment plant components.

Table 18. Estimated Costs for Coagulation, Flocculation and Sedimentation.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$2,410,380	$1,084,671	$250,000	$126,440	$471,025	$1.29
5	$7,129,080	$3,208,086	$375,000	$632,199	$1,629,955	$0.89
10	$11,394,810	$5,127,665	$562,500	$1,264,399	$2,857,002	$0.78
20	$19,000,800	$8,550,360	$1,062,500	$2,528,797	$5,191,773	$0.71

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Lime Softening

Lime softening treatment systems are designed primarily to soften hard water, reduce color and to provide the necessary treatment and disinfection to ensure the protection of public health.

Lime Softening Process

Lime softening refers to the addition of lime to raw water to reduce water hardness. When lime is added to raw water, a chemical reaction occurs that reduces water hardness by precipitating calcium carbonate and magnesium hydroxide. Disinfectant may be added at several places in the treatment process, but adequate disinfectant residual and contact time must be provided prior to distribution to the consumer. The lime softening process is effective at reducing hardness, but is relatively ineffective at controlling contaminants, such as chloride, nitrate, TTHM precursors and others (Hamann *et al*., 1990).

Lime softening is ineffective in removing the chloride ion and only fairly effective at reducing total dissolved solids (TDS). Chloride levels of raw water sources expected to serve lime-softening facilities should be below the chloride MCL to avoid possible exceedance of the standard in the treated water.

The lime softening process does not effectively remove nitrate. Lime softening facilities with raw water sources and nitrate concentrations exceeding the MCL will probably require additional treatment.

Changing *Safe Drinking Water Act* regulations for TTHMs and DBPs are resulting in the need for many existing lime softening facilities to modify their treatment processes to comply with the standards for these groups of compounds. With increasing parameters and more stringent MCLs, many utilities are using membrane water treatment processes.

Limestone Softening Costs

Cost estimates for lime softening are presented in **Table 19**. The construction costs include the lime softening treatment components, such as the head tank, aerator, clarifier, recarbonation vessel and filter, and the cost associated with the other integral treatment plant components.

Table 19. Estimated Costs for Lime Softening.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$2,415,126	$1,086,807	$250,000	$156,793	$502,028	$1.38
5	$6,207,743	$2,793,484	$375,000	$783,966	$1,655,623	$0.91
10	$9,683,226	$4,357,452	$562,500	$1,567,933	$2,926,279	$0.80
20	$15,373,835	$6,918,226	$1,062,500	$3,135,865	$5,302,435	$0.73

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Membrane Processes

Membrane technology has continued to improve as more stringent water quality regulations that are adopted by the USEPA. Membrane processes can remove dissolved salts, organic materials that react with chlorine DBP precursors, as well as provide softening. Several membrane technologies are used to treat drinking water: reverse osmosis (RO), nanofiltration, ultrafiltration and micro filtration. Each membrane process has a different ability in processing drinking water.

Reverse Osmosis Process

Reverse Osmosis (RO) is a pressure driven process that relies on forcing water molecules (feed water) through a semipermeable membrane to produce fresh water (product water). Heavy metals, dissolved salts and compounds, such as leads and nitrates are unable to pass through the membrane and are left behind to be disposed of as concentrate or reject water. Reverse Osmosis is capable of treating feed waters of up to 45,000 mg/L TDS. Most RO applications involve brackish feed waters ranging from about 1,000 to 10,000 mg/L TDS. Transmembrane operating pressures vary considerably depending on TDS concentration (**Table 20**). In addition to treating a wide range of salinities, RO is effective at rejecting naturally occurring and synthetic organic compounds, metals and microbiological contaminants. The molecular weight cutoff determines the level of rejection of a membrane.

Table 20. Reverse Osmosis Operating Pressure Ranges.

System	Transmembrane Pressure Operating Range (psi)	Feed Water TDS Range (mg/L)	Recovery Rates (%)
Ocean water	800–1,500	10,000–50,000	15–55
Standard pressure	400–650	3,500–10,000	50–85
Low pressure	200–300	500–3,500	50–85
Nanofiltration	45–150	Up to 500	75–90

Source: AWWA, 1990, Water Quality and Treatment.

Advantages of RO treatment systems include the ability to reject organic compounds associated with formation of TTHMs and other DBPs, small space requirements, modular type construction and easy expansion. Disadvantages of RO systems include high capital cost, requirements for pretreatment and posttreatment systems, high corrosivity of the product water and disposal of the reject. Reverse Osmosis is also less efficient than lime softening, so more raw water is needed to produce finished water.

Disposal of RO reject is regulated by the FDEP. Various disposal options include surface water discharge, deep well injection, land application and reuse. Whether a disposal alternative is allowable depends on the characteristics of the reject water and disposal site.

A feasibility study for co-locating seawater or brackish RO treatment facilities with electric power plants was initiated in February 2001 by the SFWMD and cosponsored by Florida Power & Light (FPL). The objective of the study was to evaluate the technical, regulatory and economic feasibility of such a co-located operation. The conclusion of the study shows that RO desalination is now technically and economically feasible. The estimated cost of $2/1000 gallons of product water at the proposed Fort Myers site is comparable to the cost at Tampa Bay Water's Big Bend project, which is operational.

Table 21 shows estimated costs for RO. The RO costs include those associated with the process and deep well disposal of the brine. The costs presented are for general RO, site-specific concentrate disposal and raw water variations can significantly affect the cost estimates. **Table 22** shows the estimated costs of a seawater desalination system. The costs include the water intake system, desalination plant, storage units, pumping and transmission systems and brine disposal.

Table 21. Estimated Costs for Reverse Osmosis.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
3	$8,694,000	$3,912,300	$125,000	$1,158,948	$2,356,200	$2.15
5	$12,537,000	$5,641,650	$250,000	$1,839,600	$3,570,170	$1.96
10	$23,058,000	$10,376,100	$437,500	$3,541,230	$6,722,778	$1.84
20	$42,840,000	$19,278,000	$875,000	$5,794,740	$11,709,464	$1.60

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Table 22. Estimated Costs for a Seawater Desalination System.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Cost ($/1000 gal)
5	$31,117,822.00	$14,159,958.00	$348,750.00	$3,151,041.00	$3.93
10	$64,301,226.00	$24,458,254.00	$781,451.00	$4,547,339.00	$3.14
15	$91,632,809.00	$32,940,471.00	$348,750.00	$7,658,079.00	$3.11
20	$127,115,674.00	$43,952,394.00	$925,685.00	$7,864,749.00	$2.78
30	$184,840,967.00	$61,867,141.00	$925,685.00	$11,332,213.00	$2.63

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Membrane Softening and Nanofiltration

Membrane softening or nanofiltration is an emerging technology in use in Florida. Membrane softening differs from standard reverse osmosis systems in that, the membrane has a higher molecular weight cutover, lower operating pressures and feed water requirements of 500 mg/L or less of TDS. One significant advantage of the membrane softening technology is its effectiveness at removing organics that function as TTHM and other DBP precursors. Given the direction of increasing federal and state regulation of drinking water quality, membrane softening seems to be a viable treatment option towards meeting future standards.

Ultrafiltration

Ultrafiltration is a pressure driven processes that removes nonionic matter, higher molecular weight substances and fractions colloids. Colloids are extremely fine sized suspended materials that will not settle out of the water column.

Microfiltration

Microfiltration is also a pressure driven process but it removes coarser materials than ultrafiltration. Although this membrane type removes micrometer and submicrometer particles, it allows dissolved substances to pass through.

Electrodialysis and Electrodialysis Reversal

Electrodialysis (ED) is an electrochemical process that involves the movement of ions through anion and cation-selective membranes from a less concentrated solution to a more concentrated solution by the application of direct electrical current. Electrodialysis Reversal (EDR) is a similar process but provides for the reversing of the electrical current, which causes a reversing in the direction of ion movement. ED and EDR are useful in desalting brackish water with TDS feedwater concentrations of up to 10,000 mg/L. However, ED/EDR is generally not considered an efficient and cost-effective organic removal process and therefore is usually not considered for TTHM precursor removal applications (AWWA, 1988).

Distillation

The distillation treatment process is based on evaporation. Salt water is boiled and the dissolved salts, which are nonvolatile, remain behind. The water vapor is cooled and condensed into fresh water. Two distinct treatment processes are in use: multistage flash distillation and multiple effect distillation.

WASTEWATER TREATMENT TECHNOLOGIES

Wastewater treatment facilities are composed of several components, which are integrated to treat wastewater to a desired quality. At a minimum, wastewater facilities in Florida provide secondary treatment. These facilities typically dispose of their effluent via deep injection wells or ocean outfalls. As these facilities find beneficial uses for this treated water, higher levels of treatment are required to meet the required water quality. For example, treatment facilities that use reclaimed water for public access irrigation must provide filtration and high-level disinfection (advanced secondary treatment). This section will discuss some of the treatment processes to produce higher quality reclaimed water.

Advanced Secondary Treatment

Advanced secondary treatment typically refers to the addition of filtration and high-level disinfection to a secondary treatment facility. Water from these facilities is usually drawn on for reuse via irrigation of public access areas.

Filtration

Filtration is a common component on advance secondary wastewater treatment, which provides a higher quality effluent that can be utilized as reclaimed water. Filtration is required of all reclaimed water that is used for public access irrigation. The cost associated with a gravity dual-media filter are presented in **Table 23**. The construction costs include all equipment, material and installation, and the operations and maintenance costs include all energy, labor and other maintenance.

Table 23. Estimated Costs for Secondary Wastewater Filtration.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$1,036,714	$466,521	$12,500	$7,139	$149,764	$0.41
5	$2,780,710	$1,251,320	$25,000	$25,301	$407,353	$0.22
10	$4,592,088	$2,066,439	$40,000	$47,021	$677,869	$0.19
20	$6,574,476	$2,958,514	$78,750	$86,571	$991,016	$0.14

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

High-Level Disinfection

The purpose of disinfection is to kill pathogenic microorganisms in wastewater before it is discharge into the environment. To achieve high-level disinfection in an advanced secondary treatment process, monitoring and chemical feed equipment also need to be included.

The costs associated with the construction of an upgraded disinfection system are provided in **Table 24**. The construction costs include the equipment and installation, and the operations and maintenance costs include energy, labor, chemicals and normal maintenance.

Table 24. Estimated Costs for High-Level Disinfection.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$169,548	$76,297	$0	$22,075	$45,280	$0.12
5	$309,828	$139,422	$0	$87,381	$129,786	$0.07
10	$438,253	$197,214	$0	$160,965	$220,947	$0.06
20	$651,598	$293,219	$0	$312,732	$401,913	$0.06

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

Advanced Wastewater Treatment

This section addresses upgrading an existing wastewater treatment facility from advanced secondary treatment to advanced wastewater treatment to achieve dentritification and phosphorus removal. In the past, advanced wastewater treatment has been associated with facilities that utilize stream discharge for effluent disposal. However, advanced wastewater treatment is being employed to allow use of reclaimed water for wetland restoration, groundwater recharge systems and other advanced uses of reclaimed water. **Table 25** presents the costs associated with upgrading the treatment from advanced secondary to advanced wastewater treatment including high-level disinfection. The costs include deep bed filters, the addition of methanol and alum to remove nitrogen and phosphorus from the wastewater, and high-level disinfection components.

Table 25. Estimated Costs for Advanced Wastewater Treatment.

Plant Capacity (MGD)	Construction Cost	Non-Construction Cost	Land Cost & Acquisition Cost	Annual O & M Cost	Equivalent Annual Cost	Cost ($/1000 gal)
1	$1,429,548	$643,297	$0	$137,970	$333,626	$0.91
5	$6,609,828	$2,974,422	$0	$689,850	$1,594,507	$0.87
10	$13,038,253	$5,867,214	$0	$1,379,700	$3,164,187	$0.87
20	$25,851,598	$11,633,219	$0	$2,759,400	$6,297,592	$0.86

Source: St. Johns River Water Management District, 1997 Updated with a Projected 2005 Construction Cost Index.

WATER TREATMENT FACILITIES

Potable Water Treatment Facilities

Potable water in the SFWMD is supplied by three main types of facilities: 1) regional public water supply treatment facilities, municipal or privately owned; 2) small developer/home owner association or utility owned public water supply treatment facilities; 3) self-supplied individual wells that serve individual residences. Many of the smaller facilities are constructed as interim facilities until regional potable water becomes available. Once regional water is available, the smaller water treatment facility is abandoned upon connection to the regional water system.

The FDEP regulates public water supply systems in the in the SFWMD. A public water supply system is defined as a system that provides water for human consumption, if the system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. In some counties, jurisdiction of smaller public water supply systems has been delegated to the local health department. The local health department regulates systems not regulated under the auspices of the FDEP (Chapter 62-550, F.A.C.).

Wastewater Treatment Facilities

Wastewater treatment in the SFWMD is provided by 1) regional wastewater treatment facilities, municipal or privately owned; 2) small developer/home owner association or utility owned wastewater treatment facilities; and 3) septic tanks.

Many of the smaller facilities are constructed on an interim basis until regional wastewater facilities become available, at which time the smaller wastewater treatment facility is abandoned upon connection to the regional wastewater system. Wastewater treatment is regulated by the FDEP for all facilities in the District. The following wastewater treatment facilities are exempt from FDEP regulation and are regulated by the local health department for each county: 1) those with a design capacity of 2,000 GPD or less, which serve the complete wastewater and disposal needs of a single establishment; or 2) septic tank drain field systems and other on-site sewage systems with subsurface disposal and a design capacity of 10,000 GPD or less, which serve the complete wastewater disposal needs of a single establishment (Chapter 62-600, F.A.C.).

All the FDEP regulated facilities within the District use the activated sludge treatment process. The methods of reclaimed water/effluent disposal include surface water discharge, reuse and deep well injection.

CHAPTER 6
Kissimmee Basin

PLAN BOUNDARIES

The Kissimmee Basin (KB) Planning Area encompasses that portion of the SFWMD extending from southern Orange County, through the Kissimmee Chain of Lakes and the Kissimmee River, to the north shore of Lake Okeechobee. The area includes parts of Orange, Osceola, Polk, Highlands, Okeechobee and Glades counties shown in **Figure 1**. The portions of these counties within the KB Planning Area will be referred to as the Orange Area, Osceola Area, Polk Area, Highlands Area, Okeechobee Area and Glades Area in this document. The boundary of the KB Planning Area generally reflects the drainage basin of the Kissimmee River. The northern and eastern portions of the planning basin are adjacent to the St. Johns River Water Management District (SJRWMD), while the western boundary is adjacent to the Southwest Florida Water Management District (SWFWMD).

PHYSICAL FEATURES

Geography and Climate

The KB Planning Area covers 3,490 square miles and has an average elevation of 63 feet. In the northern portion of the planning area, the Kissimmee Chain of Lakes is the dominant hydrologic feature, containing 176 square miles of lakes. The drainage area for the northern portion of the basin covers 1,368 square miles and the southern portions of the metro-Orlando area. The southern half of the basin, below Lake Kissimmee, has less topographic relief and is drained by the Kissimmee River. The lower river system (Lower Kissimmee Basin) covers 2,109 square miles, of which 44 square miles are lakes (SFWMD GIS data). Included in this lower portion of the planning region is the Lake Istokpoga/Indian Prairie Basin.

Average seasonal temperatures range from 60° F during the winter to 83° F during the summer. Annual average rainfall in the KB Planning Area ranges between 46 and 50 inches. Approximately 64 percent of average annual rainfall occurs during the June to September wet season. Rainfall is further discussed in the planning and appendices documents.

Physiography

The KB Planning Area has three major physiographic zones: 1) the Lake Wales Ridge, 2) the Osceola Plain and 3) the Okeechobee Plain. The Lake Wales Ridge traverses the western edge of the KB Planning Area and is bounded on the east by the Osceola and Okeechobee plains. In general, the physiographic features in the region were formed as the land mass gradually emerged from a retreating sea.

The Lake Wales Ridge is a relict beach ridge with elevations generally exceeding 100 feet, but may reach elevations over 200 feet NGVD in portions of western Orange and Osceola counties and in eastern Polk County. The crest of the ridge forms the water divide between the SFWMD and the SWFWMD. Most of the surface waters to the east of the ridge are drained towards Kissimmee River and the SFWMD. Lakes located along the ridge are generally internally drained, leaking downward into the Intermediate and Floridan Aquifer Systems.

Most of the KB Planning Area lies within the Osceola Plain, named after Osceola County, which is almost wholly encompassed within it. The Osceola Plain is a broad flat area about 40 miles wide and 100 miles long. The highest elevation of the Osceola Plain is between 90 and 95 feet near the southern part of Orlando. Elsewhere it is between 60 and 70 feet in elevation with small local relief. The Osceola Plain narrows toward the southeast where it meets the northeastern edge of the Okeechobee Plain.

The Osceola Plain has numerous lakes, including some of the largest lakes in Florida. Little research has been conducted on the geomorphology of the lakes. Most of the area's natural lakes probably originated as sinkholes when sea level was much lower than it is today. Sinkholes are common in areas that are underlain by limestone, which is soluble in water. The larger lakes may have formed over a long period through the coalescence of a large number of sinkholes.

These lakes drain into the Kissimmee River, which begins at the southern end of Lake Hatchineha and flows southward through Lake Kissimmee, and then south through the Osceola and Okeechobee plains, before flowing into Lake Okeechobee. Where the Kissimmee River flows across the Osceola Plain, it occupies a floodplain valley about a mile and a half wide. However, where the river flows in the Okeechobee Plain, the distinction between the valley and upland surface is obscure.

The Okeechobee Plain, named after Okeechobee County and the adjacent Lake Okeechobee, gradually slopes southward from an elevation of 30 to 40 feet near the top of its boundary, to about 20 feet at the north shore of Lake Okeechobee. The plain is about 30 miles wide and 30 miles long, with less local relief than the Osceola Plain.

WATER RESOURCES AND SYSTEM OVERVIEW

Regional Hydrologic Cycle

The main components of the hydrologic cycle for the KB Planning Area include precipitation, evapotranspiration and the resulting flow of surface water and groundwater. The interaction between surface water and groundwater is expressed as either recharge to or discharge from the aquifer system.

Precipitation and Evapotranspiration

The average rainfall in the KB Planning Area ranges from 46 to 50 inches per year. There is a wet season from June through October, and a dry season from November through May. The heaviest rainfall occurs in June or July, averaging 7.75 inches for the month; the lightest rainfall month is usually November or December, averaging 1.75 inches for the month. On average, 64 percent of the annual rainfall occurs in the wet season. Much of this rainfall is returned to the atmosphere by plant transpiration or evaporation from soils and water surfaces. Hydrologic and meteorologic methods are available to measure and/or estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as Evapotranspiration (ET). Precipitation minus ET is equal to the combined amounts of surface water runoff and average groundwater recharge. Evapotranspiration in south Florida returns approximately 45 inches of water per year to the atmosphere.

Surface Water Inflow and Outflow

Surface water flow includes inflow from areas adjacent to the planning basin and rainfall within the basin, storage and outflow to Lake Okeechobee via the Kissimmee River. There are several primary surface water features providing surface water drainage for the KB Planning Area. Reedy Creek, Shingle Creek and Boggy Creek, located in the northernmost section of the basin, are the primary drainage features for Orange and northern Osceola counties. The Alligator and Kissimmee Chain of Lakes act as the primary features in northern Osceola County. All of these features eventually connect to the Kissimmee River, which is the primary drainage feature of the basin.

In general, rainfall within the basin is directed to one of the hydrologic features mentioned above. There are, however, three sources of natural inflow from areas adjacent to the planning basin. These are Josephine and Arbuckle Creeks, which flow into Lake Istokpoga, and surface water from the Horse Creek Basin, which flows into Lake Hatchineha via Lake Marion Creek. All of these inflows originate in areas located within the Southwest Florida Water Management District (SWFWMD). A detailed discussion of the surface water basins within the *Kissimmee Basin Regional Water Supply Plan* (KB Plan) can be found in an appendix of that plan.

In some areas located in the Orlando metropolitan area, some surface water drainage is directed towards drainage wells, which discharge directly to the Floridan Aquifer System. These wells, constructed up until the 1970s, are generally limited to closed drainage basins in the Orlando area. An inventory of these wells was completed in 2003, and 500 known drainage wells are located in central Florida. The wells are believed to provide a significant portion of the aquifer recharge in the Orlando area. Estimates of annual recharge to the aquifer were performed by the USGS, ranging between 20 and 30 MGD. The majority of these wells is in the St. Johns River Water Management District (SJRWMD), and may represent a potential water source option for the Orange–Osceola Area.

Groundwater Flow

The components comprising groundwater flow in the KB Planning Area include groundwater inflow from the west; the difference between surface water inflow to and outflow from the KB Planning Area; and groundwater discharge to the north, east and south.

Two aquifer systems underlie the KB Planning Area, the Surficial Aquifer System (SAS) and the Floridan Aquifer System (FAS). The SAS is exposed at the land surface and is primarily recharged by rainfall. It interacts with surface water features, such as rivers, canals and lakes. The FAS is a deeper carbonate aquifer, which is overlain by a confining layer in most areas of the basin. This deeper aquifer is the primary supply source of groundwater for the basin. The FAS is recharged by groundwater inflow from outside the basin (west side) and recharge occurring in the Kissimmee Basin Region. Aquifer discharge generally occurs along the Kissimmee River and floodplain and along the St. Johns River further to the east. Portions of the FAS discharge eastward and southward into other planning areas of the District.

Surface Water Resources

Kissimmee Basin

The Kissimmee Basin has undergone over a century of development for drainage, flood control and navigation. In 1884, the Atlantic and Gulf Coast Canal and Okeechobee Land Company dredged canals to connect Lake Tohopekaliga to Lake Okeechobee via Lakes Cypress, Hatchineha and Kissimmee. The company also dredged another canal to connect Lake Okeechobee to the Gulf of Mexico through the Caloosahatchee River.

Major hurricanes swept across the state in 1926, 1928, 1945 and 1947. The storm of 1947 caused extensive flooding on the farms south of Lake Okeechobee, southeast coastal cities and suburbs and in the Kissimmee Basin. The flooding of 1947 prompted the U.S. Congress to authorize the U.S. Army Corps of Engineers (USACE) to design and construct the Central and Southern Florida Flood Control Project (C&SF Project). The construction of the C&SF Project in the Kissimmee Basin began in 1962 and was completed in 1971. This resulted in the channelization of the 103-mile Kissimmee River into a 56-mile canal. In addition, the Kissimmee Chain of Lakes was connected, and structures were added to regulate water levels.

For the purposes of discussion, the KB Planning Area has been divided at the outlet of Lake Kissimmee (S-65) into upper and lower basins. The Upper Kissimmee Basin includes 17 subbasins, while the Lower Kissimmee Basin includes nine subbasins. A detailed map of the major surface water features, including lakes, rivers, canals and structures can be found in the appendices document of the plan, entitled "Surface Water Basins."

Upper Kissimmee Basin

The Upper Kissimmee Basin is dotted with hundreds of lakes, ranging in size from less than an acre to over 55 square miles (Lake Kissimmee). The surface water drainage includes a series of interconnected lakes in its northern portion, called the Kissimmee Chain of Lakes. Trout Lake near Alligator Lake forms the drainage divide of the chain of lakes and water can be released either to the north or to the south from this point. Water flows north through several canals and smaller lakes to Lake Mary Jane; the flow proceeds through Lakes Hart, East Tohopekaliga and Tohopekaliga, then finally to Cypress Lake. Southward flow travels a shorter route through Lake Gentry and then to Cypress Lake. From Cypress Lake, water flows southward to Lake Hatchineha and then to Lake Kissimmee. Most of these lakes are shallow, with mean depths varying from 6 to 13 feet.

The major streams feeding into the Kissimmee Chain of Lakes are Shingle Creek, Reedy Creek and Boggy Creek. The headwaters for these creeks are located in urbanized portions of metro-Orlando. Flow moves southward through wetlands on the way into their respective lakes. Water levels in the Kissimmee Chain of Lakes are managed according to a fixed regulation schedule for each lake subbasin. Typically, the regulation schedules vary from high stages in the late fall and winter to low stages at the beginning of the wet season. The minimum levels are set to provide for sufficient flood control storage and navigation depths.

The headwaters of Shingle Creek are formed in the City of Orlando. The creek runs southward for 24 miles through Shingle Creek Swamp and the City of Kissimmee before discharging into Lake Tohopekaliga. Natural flow in Shingle Creek has been substantially modified having had 13 miles channelized in the 1920s and been transected by utility transmission lines and access roads. Discharges from the City of Orlando's McLeod Road Wastewater Treatment Plant were an estimated 11 MGD until flows were diverted to conservation in 1989. The District has an aggressive land purchase program in the Shingle Creek Basin in an attempt to restore portions of the channelized creek.

Reedy Creek in Osceola County represents the least disturbed of the three major creeks. Originating in Walt Disney World, Reedy Creek runs southeast for 29 miles before splitting into two branches near Cypress Lake. One branch enters Cypress Lake and the other enters Lake Hatchineha. During most of its course, the creek flows through Reedy Creek Swamp. The Reedy Creek also receives water from the Butler Chain of Lakes during periods of high lake levels. Boggy Creek has two main branches: East and West. The East Branch, which is 12 miles in length, is the main watercourse of Boggy Creek. The headwaters of this branch are formed in the city of Orlando northwest of Orlando International Airport. The East Branch runs through Boggy Creek Swamp before emptying into East Lake Tohopekaliga. The headwaters of West Branch originate in another highly urbanized area of Orlando (Lake Jessamine). The West Branch flows to Boggy Creek Swamp.

Lower Kissimmee Basin

The Lower Kissimmee Basin includes the tributary watersheds of the Kissimmee River between the outlet of Lake Kissimmee (S-65) and Lake Okeechobee. The Kissimmee River and Lake Istokpoga are the major surface water features in the basin. Fisheating Creek and Taylor Creek/Nubbin Slough are prominent surface water features in the southern region of the KB Planning Area. Fisheating Creek marks the southernmost extent of the KB Planning Area and flows into Lake Okeechobee. Taylor Creek/Nubbin Slough is the site of one of the priority cleanup projects identified as part of the Lake Okeechobee Surface Water Improvement and Management (SWIM) Plan and Everglades restoration projects. There are no known large uses of water from either creek.

The Kissimmee River was originally 103 miles in length until it was channelized in the 1960s into a 56-mile canal (C-38). The Kissimmee River is divided into five pools (pools A-E) by a series of combined locks and spillways. The water level in each of these pools is regulated according to a regulation schedule.

As a result of numerous studies on the channelization of the Kissimmee River and the associated impact on water quality, wetlands and the ecosystem, two restoration plans were developed, that, when implemented together, will restore the ecological integrity of the Kissimmee Basin—the upper basin headwaters revitalization and the lower basin restoration of the Kissimmee River.

The Kissimmee River Restoration Project, underway, will backfill 22 miles of the C-38 Canal, directing flows through the historic river channel and restoring the ecological functions of the river/floodplain system. Backfilling began in the 1990s midway between S-65A and S-65B and will continue southward to S-65D. Information on the Kissimmee River Restoration effort can be found in **Chapter 2** of this document and on the SFWMD web site available from: http://www.sfwmd.gov.

Lake Istokpoga at 44 square miles is the fifth largest lake in Florida. The lake is connected to the Kissimmee River via the Istokpoga Canal and the C-41A Canal. The Istokpoga Canal consists of two reaches, one upstream and one downstream of the G-85 Structure. The Istokpoga Canal drains into the Kissimmee River approximately 1.5 miles upstream of the S-65C Structure. These structures are scheduled for removal as part of the Kissimmee River Restoration Project. The G-85 Structure controls the rate of flow in the Istokpoga Canal. The Istokpoga Canal is proposed for modification along with replacement of the G-85 Structure, which maintains the stage of Istokpoga Canal. The restoration project is expected to reestablish the historic hydrology of the river and floodplain in areas north of the S-65E Structure. As a result, water surface elevations in the lower reach of the Istokpoga Canal, downstream of the G-85 Structure, are expected to fluctuate seasonally.

The main outlet for Lake Istokpoga is S-68, which regulates discharges from the lake to the C-40, C-41 and C-41A canals. The C-41A Canal discharges into the Kissimmee River below S-65E, passing through two additional water control structures (S-83 and S-84). The C-41 and C-40 canals also assist in discharging water from Lake Istokpoga draining to Lake Okeechobee. The C-40, C-41 and C-41A canals and associated structures make it possible to regulate the stages of Lake Istokpoga for irrigation water supply. Tests performed by the USACE, USGS and SFWMD showed design deficiencies in the S-68, S-83 and S-84 structures. These structures will be enlarged to allow design discharges from the lake. The USACE, Jacksonville District, is responsible for design and construction of structure modifications. The modifications at S-68 include adding a single bay spillway. Modifications at the S-83 and S-84 structures include the addition of a tailwater weir. Construction is scheduled to begin in early 2004 on the G-85 replacement structure (S-67), with modifications to other structures to follow.

Groundwater Resources

The hydrogeology of the Kissimmee Basin consists of three major hydrogeologic units: the Surficial Aquifer System (SAS), the intermediate confining unit, and the Floridan Aquifer System (FAS) as shown in **Figure 7. Figure 8** shows the groundwater systems in the Kissimmee Basin Planning Area.

The groundwater system in the Kissimmee Basin is readily accessible, with groundwater being the main source of water supply in central Florida, and critical for aquatic habitats and human consumption. Virtually all of the water required to meet municipal, industrial, and agricultural needs is pumped from the FAS.

The FAS consists of two distinct production zones, the upper and lower Floridan Aquifers, separated by less permeable middle semi-confining unit. As recently as 1995, about 81 percent of the total water withdrawn from the FAS was from the upper Floridan Aquifer. However, with increasing water demands, the lower Floridan Aquifer is being used as a source of freshwater, particularly for municipal needs in Orange County.

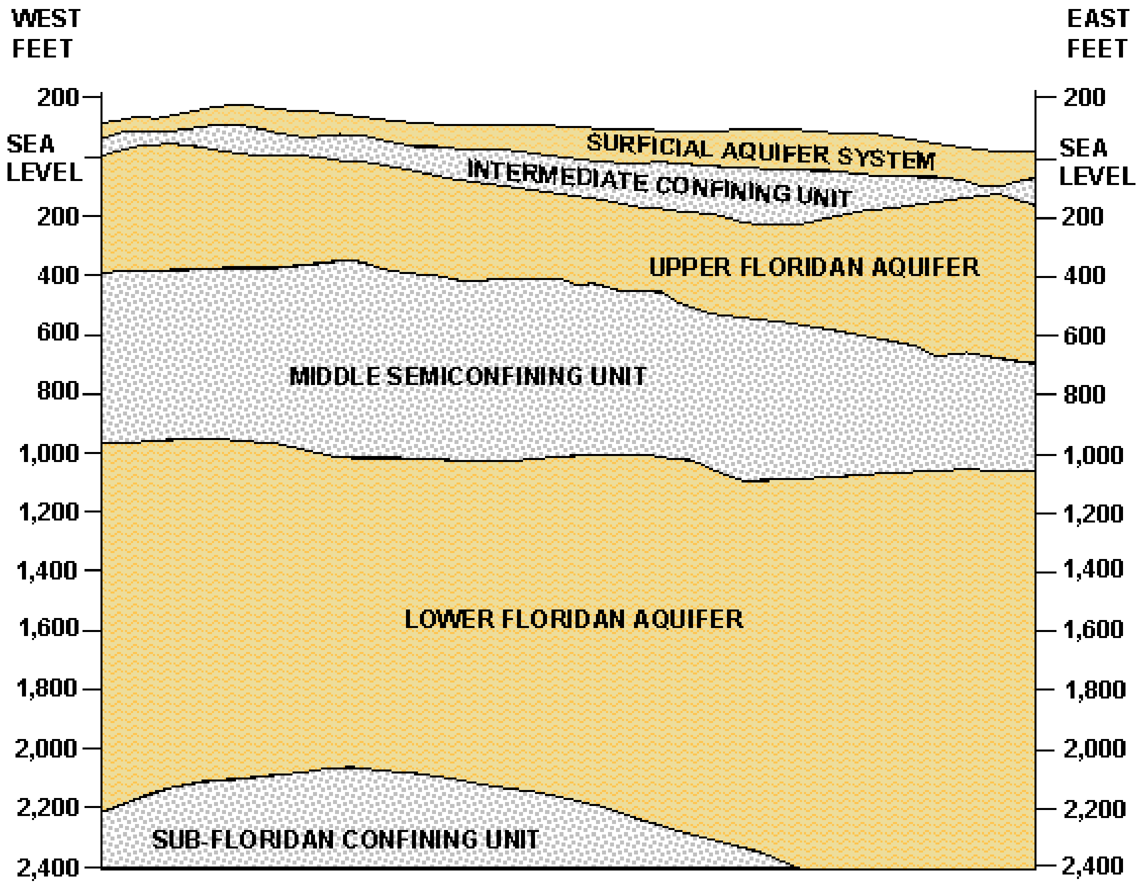


Figure 7. Generalized Geologic Cross-Section of the Kissimmee Basin.

SERIES		STRATIGRAPHIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT	
Holocene		Undifferentiated deposits	Alluvium, freshwater marl, peats and muds in stream and lake bottoms. Also, some dunes and other windblown sand.	Surficial aquifer system	
Pleistocene			Mostly quartz sand. Locally may contain deposits of shell and thin beds of clay.		
Pliocene			Interbedded deposits of sand, shell fragments, and sandy clay; base may contain phosphatic clay.		
Miocene		Hawthorn Group	Interbedded quartz, sand, silt and clay, often phosphatic; phosphatic limestone often found at base of formation.	Intermediate confining unit	
Eocene	Upper	Ocala Limestone	Cream to tan, soft to hard, granular, porous, foraminiferal limestone.	Floridan aquifer system	Upper Floridan aquifer
	Middle	Avon Park Formation	Light brown to brown, soft to hard, porous to dense, granular to chalky, fossiliferous limestone and brown, crystalline dolomite; intergranular gypsum and anhydrite.		Middle semiconfining unit / Middle confining unit
	Lower	Oldsmar Formation	Alternating beds of light brown to white, chalky, porous, fossiliferous limestone and porous crystalline dolomite.		Lower Floridan aquifer
Paleocene		Cedar Keys Formation	Dolomite, with considerable anhydrite and gypsum, some limestone.	Sub-Floridan confining unit	

Figure 8. Groundwater Systems in the Kissimmee Basin (from O'Reilly, 2002).

Surficial Aquifer System

The Surficial Aquifer System (SAS) is unconfined and consists of fine-to-medium grained quartz sand with varying amounts of silt, clay, and crushed shell, of Holocene and Pleistocene age. This uppermost aquifer is also called the Water Table Aquifer. It extends from land surface at the northern parts of the Kissimmee Basin to a depth of about 270 feet in parts of Polk County within the boundaries of the South Florida Water Management District. The SAS produces small quantities of good-to-fair quality water. It is generally soft, low in mineral content, slightly corrosive, and often high in color and iron.

Due to the low yield, wells completed in the SAS are limited to residential self-supply, lawn irrigation, and small-scale agricultural irrigation. The SAS is the major source for domestic self-supplied use in Okeechobee County. This shallow groundwater contains relatively high chloride and dissolved solids concentrations as you move to the western part of this county and near the Caloosahatchee River in Glades County. **Tables 26** through **31** list the water resource potential of each aquifer per county.

Intermediate Aquifer System

The Intermediate Aquifer System (IAS) acts as a confining unit for the underlying FAS in the Kissimmee Basin area. A few locally occurring producing zones exist, but they do not produce large amounts of water. The IAS includes all sediments of late-to-middle Miocene age (Hawthorn Group), and low permeability beds of early Pliocene age (Miller, 1986). The top of this unit is usually recognized by the first occurrence of a distinct and persistent greenish color. The unit consists of interbedded sands, calcareous silts and clays, shell, and phosphatic limestone and dolomite. These clays, silts, and fine sands of the Hawthorn Formation retard vertical movement of water between the Water Table Aquifer and the underlying FAS. The thickness of this intermediate confining unit ranges from less than 50 feet in the northern portion of the basin to over 600 feet in parts of Okeechobee and Highlands counties.

Florida Aquifer System

The Floridan Aquifer System (FAS) is the primary source for potable water in the Kissimmee Basin and capable of producing large amounts of water. The aquifer is composed of a sequence of highly permeable carbonate rocks (limestone and dolomite) of Oligocene, Eocene and Late Paleocene age. The FAS is a confined or semi-confined aquifer within the basin boundaries. It contains two major producing zones, the upper and lower Floridan Aquifers. The middle semi-confining unit separates these units. The FAS has an average thickness of approximately 2,300 feet within the basin but few wells have penetrated the entire FAS. The altitude of the top of the upper Floridan Aquifer ranges from 100 feet above sea level in parts northern Polk County to more than 1600 feet below sea level in the southwestern portion of the basin. The upper Floridan Aquifer is thicker in Glades and Okeechobee counties, averaging approximately 1,000 feet. However, chloride, total dissolved solids (TDS), and sulfate concentrations increase with depth and distance to the south, limiting the potential large consumptive use without expensive treatment.

The upper Floridan Aquifer in the northern portion of the basin is recharged primarily by downward leakage from the SAS, and where present, through the intermediate confining unit. Higher rates of recharge occur in areas with abundant sinkholes where the intermediate confining unit is thin or breached by collapse into underlying dissolution cavities. The upper Floridan Aquifer can also be recharged by the lower Floridan Aquifer depending on the conditions of the middle semi-confining unit that separates the two members of the FAS.

The lower Floridan Aquifer is present throughout east-central Florida (O'Reilly and others, 2002). The altitude of the top of the lower Floridan Aquifer ranges from 600 feet below sea level to more than 1,600 feet below sea level in the lower portion of the Kissimmee Basin. The lower Floridan Aquifer consists of the lower part of the Avon Park Formation of middle Eocene age, and the upper part of the Cedar Keys Formation of late Paleocene age. The lower Floridan Aquifer is composed of alternating beds of limestone and dolomite and is characterized by abundant fractures and solution cavities.

Surface Water / Groundwater Relationships

The relationship between a surface water feature and the underlying groundwater system is one of the most difficult hydrologic relationships to understand. This relationship is based upon the hydraulic characteristics of each aquifer and the thickness and type of soils separating the two features. When a river, canal or wetland has a higher water level than the water table, these surface water bodies provide seepage into the local shallow groundwater system. Conversely, when the water level of the surface water bodies are lower than the water table, groundwater discharge may occur. The rate at which this transfer occurs is dependent upon the difference in these two levels and the permeability and thickness of the materials separating the two aquifers.

The FAS experiences both natural and artificial recharge. Natural recharge of the FAS within the KB Planning Area is greatest along the Lake Wales, Mount Dora and Bombing Range ridges. These areas represent locations where the differences in surface and FAS levels are greatest, and the thickness of the IAS is thinnest or breached by karst activity. Recharge areas are often evident as potentiometric highs on the surface of the FAS. This is not always the case however. The potentiometric high located in Polk County is not a high recharge, but is instead an artifact of the several surrounding discharge areas. Along the eastern part of the Green Swamp, high recharge occurs in the sand-filled cavities that extend into the top of the UFA along U.S. Highway 27 at the edge, and not in the middle of Green Swamp.

There are an estimated 500 drainage wells in central Florida that discharge into the FAS. Approximately 50 percent of the water these drainage wells receive is from direct storm water runoff; another 30 percent is from lake overflow; while the remaining percentage is from excess overflow from wetlands and unused wells that in the past were used to dispose of industrial effluent, sewage and air conditioner return water.

Table 26. Groundwater Systems in Orange County.

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated Clastic Deposits	0-100	Yields low to moderate amounts of water to wells. Used sporadically as a source of individual domestic supply in a few areas.
Intermediate Aquifer System	Hawthorn Group Confining Beds	50-250	Acts as a confining zone for the underlying FAS. A few locally occurring producing zones exist, but they do not produce large amounts of water. Some limited domestic use occurs.
Upper Floridan Aquifer	Ocala Limestone and Avon Park Limestone	200-400	Capable of producing large amounts of water. Susceptible to local contamination as a result of receiving surface runoff through drainage wells.
Middle Semi-Confining Unit	Lower Avon Park and Upper Lake City	300-700	Unit separating the upper and lower producing units.
Lower Floridan Aquifer	Lake City and Oldsmar Limestone	1,100-1,600	Yields generally exceed 2,000 GPM. Yield can be less predictable than the upper zone as less is known about this aquifer.

Table 27. Groundwater Systems in Osceola County.

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated clastic deposits	20-270	Yields low to moderate amounts of water to wells. Not a major water source in Osceola County. Water quality varies widely.
Intermediate Confining Unit	Hawthorn Group	10-370	Acts as a confining zone for the underlying FAS. There may be limestone units within the Hawthorn Group, which may produce moderate amounts of water. These units have not been studied extensively.
Upper Floridan Aquifer	Ocala Group and Avon Park Limestone	100-500	Capable of producing large amounts of water. In general, the upper zone produces more water than the lower zone.
Middle Semi-Confining Unit	Lower Avon Park and Upper Lake City	450-700	Acts as a confining zone for the lower producing zone, although capable of producing significant amounts of water in some areas of the county.
Lower Floridan Aquifer	Lake City Limestone	1,400-2,130	Capable of producing large amounts of water. Water quality limitations on the eastern side of the county.

Table 28. Groundwater Systems in Polk County.

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated clastic deposits	10-100	Produces small quantities of relatively good quality water. Most wells yield less than 50 GPM. Use is restricted to residential self-supply, lawn irrigation and small-scale agricultural irrigation.
Intermediate Aquifer System	Hawthorn Group	10-300	Used primarily for residential self-supply, livestock watering and small public utilities. The aquifer produces small to moderate quantities of potable quality water. Most productive in the central and southern portions of the county.
Upper Floridan Aquifer	Tampa Member, Suwannee and Ocala Limestones, Upper portion of Avon Park	300-600	Principal aquifer in Polk County. Supplies all major municipal, industrial and irrigation water demands. Produces large quantities of good quality water. Eastern portions of the county experience artesian conditions.
Middle Semi-Confining Unit	Lower Avon Park, Lake City Limestone	200-400	Lower yielding portions of the Avon Park. Introduction of dolomites reduces permeabilities.
Lower Floridan Aquifer	Lake City and Oldsmar Limestone	>600	Little is known of this portion of the Floridan system, as it is not extensively used. It is believed that transmissivity for the aquifer is less than that of the upper section.

Table 29. Groundwater Systems in Highlands County.

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated clastic deposits and Tamiami Formation	40-200	Except for isolated areas with high iron and organics, produces small to moderate amounts of good quality water. Furnishes residential self-supplied and livestock watering locally throughout the county.
Intermediate Aquifer System	Hawthorn Group	300-650	Confining unit for the FAS. Isolated beds of sand and gravel yield large amounts of water locally along the ridge, but they are discontinuous. Not an important source of water over most of the county.
Floridan Aquifer System	Suwannee Limestone	0-80	Most important source of water in Highlands County. Productivity tends to increase with depth. Total dissolved solids, sulfates and chloride concentrations increase with depth and distance to the south from the Highlands Ridge, but water of a quality acceptable for most uses can be found as deep as the Lake City Limestone.
	Ocala Limestone	150-250	
	Moody's Branch Formation	50-150	
	Avon Park Limestone	200-300	
	Lake City Limestone	>400	
	Oldsmar Limestone	>600	
	Cedar Keys Limestone	>670	Water is too highly mineralized for most purposes.

Table 30. Groundwater Systems In Okeechobee County

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated clastic deposits	100-240	Yields small quantities of good quality water, except near Lake Okeechobee where chloride concentrations exceed potable standards. Wells commonly yield 100 GPM or less. The SAS is the primary source of potable water in unincorporated areas.
Intermediate Aquifer System	Hawthorn Group	200-600	Does not yield significant quantities of water within Okeechobee County.
Upper Floridan Aquifer	Ocala and Avon Park Limestone Formation	860-960	Produces large to moderate quantities of water, with productivity increasing to the north. Wells generally yield more than 200 GPM. Water quality varies, ranging from very good in the north to brackish in the south and east. The FAS is the primary source of supply of agricultural uses. Sodium, chloride, TDS and sulfate concentrations increase with depth throughout the county.
Middle Floridan Unit			Little information is available about this unit.
Lower Floridan Aquifer			Little is known about this aquifer because few wells penetrate this unit. Water quality is generally known to be poor exceeding chloride concentrations of 1,000 mg/L in locations.

Table 31. Groundwater Systems in Glades County.

Hydrogeologic System	Geologic Unit	Thickness (feet)	Water Resource Potential
Surficial Aquifer System	Undifferentiated clastic deposits	20-100	Varies widely in productivity. Near Lake Okeechobee, the shallow groundwater is high in chlorides. Moore Haven obtains its potable water from the SAS.
	Tamiami Formation	0-100	Source of some domestic and stock supply wells.
Intermediate Aquifer System	Equivalent to the sandstone aquifer of Hendry and Lee Counties	90-230	Low to moderate productivity. Supplies water for residential self-supplied use and for irrigating small citrus groves.
Floridan Aquifer System	Suwannee Limestone Ocala Limestone	270-1,200	Artesian flow through much of the county. High productivity. Potable in the north to unsuitable for irrigation in the south. Chloride, TDS and sulfate concentrations increase with depth throughout the county.

WATER NEEDS OF INLAND RESOURCES

Wetland Water Needs and Concerns

Maintaining appropriate wetland hydrology (water levels and hydroperiod) is the single most critical factor in maintaining a viable wetland ecosystem. Rainfall, along with associated groundwater and surface water inflows, is the primary source of water for the majority of wetlands in the KB Planning Area. Because wetlands exist along a continuous gradient, changes in the hydrologic regime may result in a change in the position of plant and animal communities along the gradient. The effects of hydrologic change are both complex and subtle. They are influenced by, and reflect regional processes and impacts, as well as local ones.

Rivers and Floodplains

The Kissimmee River and its floodplains contain forested, wetland shrub and marsh wetlands, and at one time meandered through the Osceola Plain. In addition to serving as a temporary water storage system, the floodplain along the Kissimmee River served as a filtration system, regulating the velocity and timing of the flood discharge by slowing the waters that spilled over the banks of the river. Pollutants and nutrients (nitrogen and phosphorus) were taken up by the floodplain vegetation before water flowed into Lake Okeechobee or seeped into the aquifer.

The floodplain supported diverse vegetation, which in turn sustained huge populations of fish and wildlife. During the 1960s however, the natural curves and extensive floodplain of the Kissimmee River were replaced with a straighter, more drainage-efficient waterway for navigation and flood control purposes. Unfortunately, this resulted in the loss of thousands of acres of wetlands and riverine habitat. Migratory waterfowl decreased by 92 percent and the bald eagle population by 74 percent. The food chain base became depleted as small fish, shrimp and invertebrates disappeared along with their wetland habitat. Fisheries dwindled and game fish catch declined by half.

Restoration of parts of the river is taking place, restoring wetland habitat values. The premise of the federally authorized Kissimmee River Restoration Project is restoration in its truest sense—to reestablish natural water levels and flow and to restore the ecological integrity of the watershed. The restoration project will restore over 40 square miles of the existing channelized system, including 43 continuous miles of meandering river channel and about 27,000 acres of wetlands. The project is expected to benefit over 320 fish and wildlife species.

Lakes

The KB Planning Area has hundreds of lakes. A lake can be classified according to its trophic level. Oligotrophic lakes have low levels of nutrients, good water clarity and low levels of plant and animal life. Mesotrophic lakes have moderate levels of nutrients, moderate water clarity and a moderate amount of plants and animals. High levels of nutrients, reduced water clarity and an abundance of aquatic plant and animal life characterize eutrophic lakes. Hypereutrophic lakes are those that often have a pea soup appearance from the amount of algae in the water column, the presence of algal mats and an overabundance of nutrients. As rotting plant material uses oxygen, aquatic animal life may die off from a lack of dissolved oxygen in the water. Eventually, the mucky bottom of the lake fills up with sediments and converts into a marsh. Eutrophication is a natural process; however, human activities can accelerate this process (cultural eutrophication).

A decrease in nutrients to the lake systems should slow eutrophication. In the 1970s, the water quality in the Upper Kissimmee Basin (especially Lake Tohopekaliga) was significantly degraded by nutrients that originated from sewage treatment plants in Orlando, and from untreated nonpoint urban and agricultural sources. When the nutrient sources were identified and consequently reduced or eliminated, the water quality in the lakes improved. Better water quality in the Upper Kissimmee Basin may lead to improved quality in the Lower Kissimmee Basin and Lake Okeechobee.

Springs

Springs occur at locations where there is a direct location between an aquifer and surface waters. Florida has more springs than any other state, with 27 first magnitude springs having an average flow of 65 MGD or more. The state also has 49 springs with an average flow of between 6.5 and 65 MGD. These major springs result from the upward movement of water from the FAS in areas where the artesian pressure in the aquifer is elevated above the land surface. Although there are no known documented natural springs located within the KB Planning Area, there are anecdotal discussions with local residents of existing shallow aquifer seeps or springs located along the eastern edge of the Lake Wales Ridge in Polk County or possibly along the Kissimmee River. The location of these springs has not been identified.

There are several natural springs located adjacent to, but outside the KB Planning Area. The most noteworthy of these are the springs of the Wekiva Basin, located approximately 15 miles to the north of the KB Planning Area in northwestern Orange County. These springs are the result of discharges from the FAS in areas where the confining units are thin and have been breached, allowing for the upward artesian flow of water. Discharges from seven of the springs flow to the Wekiva River, a protected Outstanding Florida Waterway. These springs include Wekiva, Sanlando, Starbuck, Miami, Rock, Palm and Seminole springs. The St. Johns River Water Management District (SJRWMD) has determined that these springs provide an important base flow component to the river and to those vegetative communities dependant on this water. The SJRWMD has determined that a 15 percent reduction in the 1995 observed spring discharge for these seven springs is enough to pose a reasonable likelihood of harm to natural systems along the Wekiva River and its tributaries. These minimum spring discharges have been set forth in Chapter 40C-8, F.A.C. This chapter also specifies specific minimum discharges for several springs located in the Wekiva Basin and throughout the SJRWMD.

The SJRWMD Water Supply Needs and Sources Assessment (SJRWMD 1994) projects that future groundwater withdrawals from the metro-Orlando area, including withdrawals occurring in both the SJRWMD and SFWMD, are contributing to the reduction of annual average discharges from freshwater springs located in the Wekiva Basin and along the St. Johns River. The KB Plan addresses these issues and provides further assessment of the linkage between the FAS and the reduction of spring flows in these areas. This assessment is addressed in the *Kissimmee Basin Regional Water Supply Plan* (KB Plan) planning document.

CHAPTER 7
Upper East Coast

PLAN BOUNDARIES

The Upper East Coast (UEC) Planning Area incorporates the northern reaches of the SFWMD on the east coast. The area includes Martin and St. Lucie counties, and a small portion of Okeechobee County, as shown in **Figure 1**. The portion of Okeechobee County within the planning area will be referred to as the Okeechobee Area in this document. The boundary of the UEC Planning Area generally reflects the drainage basins of the C-23, C-24, C-25 and C-44 (St. Lucie Canal) canals. The northern boundary corresponds to the St. Lucie–Indian River County line, which is also the SFWMD/SJRWMD jurisdictional boundary. The southern boundary is the Martin–Palm Beach County line.

PHYSICAL FEATURES

Geography and Climate

The UEC Planning Area covers approximately 1,430 square miles and has an average elevation of 20 feet. Average seasonal temperatures range from 64 degrees during the winter to about 81 degrees during the summer (University of Florida, 1993). Annual average rainfall in the planning area is about 51 inches. About 72 percent of the annual rainfall occurs during the May through October wet season.

Physiography

The UEC Area is characterized by three principal physiographic zones, which generally trend from east to west. These zones are identified as: 1) the Atlantic Coastal Ridge, 2) the Eastern Valley and 3) the Osceola Plain. The Atlantic Coastal Ridge, made of relict beach ridges and sand bars, parallels the coast and has a width ranging from several hundred feet to a couple of miles. The ridge varies in elevation from sea level to a high of 86 feet above sea level in the sand hills of Jonathan Dickinson State Park.

West of the Atlantic Coastal Ridge is the Eastern Valley, which is a flat relict beach ridge plain. Most of the planning area lies within the Eastern Valley. The valley is generally lower than the ridge, with land elevations ranging from 15 to 30 feet above mean sea level, and an average width of 30 miles. These areas are characteristically pocketed with shallow lakes and marshes and have limited natural drainage. Prior to development and construction of canals, the valley drained by a slow drift of water through multiple sloughs to the St. Lucie River, the Loxahatchee River and the Everglades. This area contains the Savannas State Park, Pal-Mar, Loxahatchee Slough and the Allapattah, St. Lucie and Osceola Flats.

The Osceola Plain lies west of the Eastern Valley in St. Lucie County and intrudes into the Eastern Valley in Martin County, where it terminates at Indiantown. The elevation of the plain in Martin County is approximately 40 feet.

WATER RESOURCES AND SYSTEM OVERVIEW

Regional Hydrologic Cycle

The main components of the hydrologic cycle in the UEC Planning Area are precipitation, evapotranspiration, surface water inflow and outflow and groundwater flow.

Precipitation and Evapotranspiration

The average rainfall in the planning area is about 51 inches per year, but varies considerably from year to year. There is a wet season from May through October, and a dry season from November through April. The maximum monthly average rainfall is 7.52 inches in September (St. Lucie County) and the minimum monthly average rainfall is 1.93 inches in December (Martin County). Monthly rainfall displays a higher measure of relative variability during the dry period. Rainfall also varies areally (from location to location), with rainfall amounts generally decreasing from east to west, especially during the wet season. Management of surface water systems is one of the main factors affecting movement of water through the regional hydrologic cycle.

Surface Water Inflow and Outflow

Essentially all surface water inflows and outflows in the planning area are derived from rainfall. The exception to this is the St. Lucie Canal (C-44), which also receives water from Lake Okeechobee. In addition, most of the flows and stages in the region’s canals are regulated for water use and flood protection. The amount of stored water is of critical importance to both the natural ecosystems and the developed areas in the UEC Planning Area. Management of surface water storage capacity involves balancing two conflicting conditions. When there is little water in storage, drought conditions may occur during periods of deficient rainfall. Conversely, when storage is at capacity, flooding may occur due to excessive rainfall, especially during the wet season. Management of surface water systems is one of the main factors affecting movement of water through the regional hydrologic cycle.

Groundwater Flow

Another distinctive feature of south Florida’s hydrologic system is the aquifer system and its use for water supply. Two vast aquifer systems, the Surficial Aquifer System (SAS) and the Floridan Aquifer System (FAS), underlie the planning area. Groundwater inflows from outside the planning area form an insignificant portion of recharge to the SAS. Rainfall is the main source of recharge to the SAS, and because of this, long-term utilization of this source must be governed by local and regional recharge rates. The FAS receives most of its recharge from outside of the UEC Planning Area. This fact must also be incorporated into long-term planning decisions.

Surface Water Resources

Prior to development, most of the UEC Planning Area was characterized by nearly level, poorly drained lands subject to frequent flooding. The natural surface drainage systems included large expanses of sloughs and marshes, such as St. Johns Marsh, Allapattah Slough (also referred to as Allapattah Flats), Cane Slough and the Savannas. Drainage systems with higher conveyance included the North and South Forks of the St. Lucie River, Ten Mile Creek, Five Mile Creek, the Loxahatchee River and Bessey Creek. Most of these surface water systems, especially those with poor drainage, have been altered to make the land suitable for development and to provide flood protection.

Since the early 1900s, numerous water control facilities have been constructed to make this region suitable for agricultural, industrial and residential use. The St. Lucie Canal (C-44) was constructed between 1916 and 1924 to provide an improved outlet for Lake Okeechobee floodwaters. From 1918 to 1919, the Fort Pierce Farms Water Control District (FPFWCD) and the North St. Lucie River Water Control District (NSLRWCD) were formed to provide flood control and drainage for citrus production in east-central and northeastern St. Lucie County. The C-25 Canal (also known as Belcher Canal) provided a drainage outlet for the FPFWCD, as well as limited flood protection for western areas of the basin. The C-24 Canal (also known as the Diversion Canal) provided drainage and limited flood protection west of the NSLRWCD protection levee. The C-23 Canal provided water control in Allapattah Flats during the dry season. However, large areas continued to be under water for months at a time during the wet season.

Torrential rains and extensive flooding in South Florida in 1947 prompted the U.S. Congress to authorize the design and construction of the Central and Southern Florida Flood Control Project (C&SF Project). The C&SF Project included construction of levees, canals, spillways, pump stations and dams. Within the area that is now the UEC Planning Area; the project incorporated the existing canals and provided increased outlet capacity for Lake Okeechobee by making improvements to the St. Lucie Canal.

The U.S. Army Corps of Engineers (USACE) in their General Design Memorandum for the C&SF Project (1957) first delineated surface water management basins in the UEC Planning Area in the 1950s. The C&SF Project works serve nine basins in the planning area. Detailed descriptions of these basins can be found in the atlases of surface water management basins for Martin County (Cooper and Santee, 1988) and St. Lucie County (Cooper and Ortel, 1988).

There are 12 basins without C&SF Project works in the planning area. The level of flood protection in these basins varies widely, depending on the conveyance of the natural drainage system and extent of land development. Water control districts have been established in some basins to provide drainage, flood control and water supply.

Surface Water Planning Areas

The sections to follow provide a description of the surface water resources for basins within the UEC Planning Area. Because adjacent basins tend to have similar needs and resources, the basins have been grouped into five geographical planning areas for the purposes of this report. These areas are the: 1) St. Lucie Agricultural Area; 2) Eastern St. Lucie Area; 3) St. Lucie River Area; 4) Southeastern Martin Area; and 5) Tidal Area.

St. Lucie Agricultural Area

The St. Lucie Agricultural Area is located in western St. Lucie County, eastern Okeechobee County and northern Martin County. It includes all of the C-23, C-24, C-25 basins and parts of the North Fork St. Lucie River Basin.

The C-23, C-24 and C-25 canals and control structures were improved under the C&SF Project. Their current functions are: 1) to remove excess water from their respective basins; 2) to supply water during periods of low rainfall; and 3) to maintain groundwater table elevations at the coastal structures to prevent saltwater intrusion.

The canals and control structures were designed to pass 30 percent of the Standard Project Flood (SPF), a mathematically derived severe storm event, and to meet irrigation delivery requirements for the basin. In this planning area, SPF is statistically equivalent to a 10-year, 72-hour storm event. Excess water may be discharged from C-25 to tidewater by way of S-99 and S-50 or to C-24 by way of G-81. Excess water in C-24 may be discharged to tidewater by way of S-49, to C-25 by way of G-81 or to C-23 by way of G-78. Excess water in C-23 may be discharged to tidewater by way of S-97 and S-48 or to C-24 by way of G-78. A 1993 study concluded that the capacity of the C-23 was insufficient to convey design flows within the banks (SFWMD, 1993).

Flow in each of the C&SF Project canals is regulated by their respective control structures. For flood control and drainage, water elevations in the canal are set far enough below ground surface to provide slope in the secondary drainage systems. Water supply requires the water surface in the primary canal be maintained sufficiently high to prevent overdrainage. When flow in the canals is adequate, control structures are operated to maintain a headwater stage within a seasonally dependent range (**Table 32**).

Table 32. Optimal Headwater Stage for Project Canals.

Canal	Structure	Headwater Stage (ft. NGVD)	
		Wet Season[a]	Dry Season
C-25	S-99	19.2-20.2	21.5-22.5
C-25	S-50	>12.0	>12.0
C-24	S-49	18.5-20.2	19.5-21.2
C-23	S-97	20.5-22.2	22.2-23.2
C-23	S-48	>8.0	>8.0

a. Wet season is from May 15 to October 15.
Source: Cooper and Ortel, 1988.

Although the primary function of the C&SF Project was for flood control and drainage, the drainage network formed by the C&SF Project canals and the secondary canals and ditches has become an important source of irrigation for agriculture. In general, water stored in the canals is replenished by rainfall, groundwater inflow and runoff.

Prior to the large-scale expansion of citrus in the 1960s, storage in the drainage network in St. Lucie County was adequate to meet irrigation demands. However, the drainage and development of the large marsh areas in western St. Lucie County have depleted much of the surface water storage. The lowering of water tables has also reduced the amount of water in groundwater storage. The reduction of surface and groundwater storage coupled with increased acreages of citrus has resulted in inadequate supplies of surface water to meet demands during droughts. Surface water availability in the C-23, C-24 and C-25 basins is restricted when water levels reach 14.0 feet NGVD. Artesian well water from the FAS is used as an irrigation supplement when surface water supplies become limited. Due to the high mineral content of the Floridan Aquifer, this water is generally blended with surface water before it is used as irrigation water.

The original General Design Memorandum envisioned a large conservation area north of C-25 in the St. Johns Marsh. The C-23, C-24 and C-25 canals and associated control structures were designed to deliver irrigation water from the water conservation area to 320 square miles of land in St. Lucie County. However, this portion of the C&SF Project was redesigned without the water conservation area due to local opposition to taking 200,000 acres of the floodplain out of production. Another proposal would have provided a link from Lake Okeechobee to C-23. This proposed C-131 Canal and its associated control structures and pumps would have supplied irrigation water to St. Lucie County, and permitted backflow of surplus rainfall runoff from the C-23, C-24 and C-25 basins into Lake Okeechobee. The C-131 proposal was later modified to include a flowway adjacent to C-131, which was designed to improve the water quality of the backflow prior to discharging into Lake Okeechobee. Although the flowway would have resolved the water quality concerns, it significantly increased the cost of the project, making the overall project economically unviable.

Eastern St. Lucie Area

The Eastern St. Lucie Area includes most of the North Fork St. Lucie River Basin. The North Fork St. Lucie Basin is a 169-mile (108,165 acres) watershed located in the northern part of the planning area. The North Fork of the St. Lucie River is fed by Five Mile Creek and Ten Mile Creek at the north end and flows south until it merges with the C-23 Canal at the headwaters of the St. Lucie Estuary.

There are two C&SF Project canals (C-23A and C-24) in the North Fork St. Lucie River Basin. Canal C-23A is a short section of canal in the lower reach of the North Fork of the St. Lucie River. This canal passes discharges for both the North Fork of the St. Lucie River and the C-24 Canal to the St. Lucie River Estuary. A short reach of the C-24 Canal extends from the S-49 Structure to the North Fork of the St. Lucie River, just north of C-23A. C-23A was designed to pass 30 percent of the Standard Project Flood (SPF) from the North Fork St. Lucie River Basin and from the C-24 Basin.

Two drainage districts in the Eastern St. Lucie Area have been established to coordinate surface water management within their districts. The districts are the Fort Pierce Farms Water Control District (FPFWCD) and the North St. Lucie River Water Control District (NSLRWCD). The City of Port St. Lucie has also established the Port St. Lucie Storm Water Utility (PSLSWU).

The FPFWCD was originally created as the Fort Pierce Farms Drainage District in 1919, under the provisions of Chapter 298, F.S., incorporating 15,000 acres of land in the basin. All canals in the FPFWCD system drain to Canal 1, which discharges to the lower reach of C-25.

The NSLRWCD was originally created as the North St. Lucie River Drainage District in 1918, under the provisions of Chapter 298, F.S., incorporating 65,000 acres in the North Fork of the St. Lucie River Basin. The water control system consists of man-made canals, improved natural streams and control structures.

The Header Canal is parallel to the west boundary NSLRWCD, and is located 3 miles east of the north-south reach of the C-24 Canal. It collects runoff from secondary canals extending westward, and it is connected to Ten Mile Creek to the east, C-25 to the north and C-24 to the south. Ten Mile Creek and Five Mile Creek are natural streams, having been improved to transport water from the secondary drainage system to the North Fork of the St. Lucie River.

Water control structures in both FPFWCD and NSLRWCD are regulated on a day-to-day basis to maintain optimum canal water levels for agricultural production. During the dry season and as canal stages permit, water can be diverted from C-25 to FPFWCD for irrigation. Stage levels in the Header Canal are maintained by backpumping water from Ten Mile Creek.

St. Lucie River Area

The St. Lucie River Area covers most of Martin County. It can be subdivided in two categories: 1) the Canal Area, which includes all of the C-44, S-153 and Tidal St. Lucie basins served by C&SF Project canals; and 2) basins 4, 5, 6 and 8. Basin 8 drains out of the UEC Planning Area and has little interaction with the St. Lucie River Area.

The Canal Area contains the only basin (C-44 Basin) in the UEC Planning Area that is hydrologically connected to Lake Okeechobee. Therefore, this section includes a discussion of the lake's regulation schedule.

Canal Area

The C&SF Project canal and control structures in the C-44 Basin have five functions: 1) to provide drainage and flood protection for the C-44 Basin; 2) to accept runoff from the S-153 Basin and discharge this runoff to tidewater; 3) to discharge water from Lake Okeechobee to tidewater when the lake is over schedule; 4) to supply water to the C-44 Basin during periods of low natural flow; and 5) to provide a navigable waterway from Lake Okeechobee to the Intracoastal Waterway. Excess water is discharged to tidewater by way of S-80 and C-44A. Under certain conditions, excess water may backflow to Lake Okeechobee by way of S-308. Regulatory releases from Lake Okeechobee are made to C-44 by way of S-308. Water supply to the basin is made from Lake Okeechobee by way of S-308 and from local rainfall. Both S-80 and S-308 have navigation locks to pass boat traffic.

Lockages are performed on an "on-demand" basis at S-80, except when water shortages have been declared or maintenance and repairs to the structure are taking place. Although there is no formal water shortage plan for S-80, the USACE will curtail lockages at the request of the District. Maintenance and repairs that result in interruptions of lockages are done on an as-needed basis, usually occurring every three to five years. Each lockage at S-80 releases over 1.3 million gallons of water. The average number of lockages at S-80 varies monthly.

The S-153 Structure provides flood protection and drainage for the S-153 Basin. Excess water in the basin is discharged to C-44 by way of the L-65 Borrow Canal and S-153. The cooling reservoir for the Florida Power and Light power plant was originally part of the S-153 Basin. This 6,600-acre reservoir is now hydraulically connected to C-44, and is considered part of the C-44 Basin. The S-153 Structure is operated to maintain an optimum stage of 18.8 feet NGVD.

The S-80 Structure in the Tidal St. Lucie Basin has three functions: 1) to accept flow from C-44 and to discharge those flows to tidewater in the St. Lucie River; 2) to provide a navigable waterway from the St. Lucie Canal to the Intracoastal Waterway; and 3) to provide drainage for portions of the Tidal St. Lucie Basin.

C-44 and S-80 were designed to pass the SPF from the C-44 Basin and the S-153 Basin and to pass regulatory discharges from Lake Okeechobee to tidewater. The S-308 and S-80 Structures are operated to maintain an optimum canal stage of 14.5 feet NGVD within the Tidal St. Lucie Basin.

Basins 4, 5 and 6

Bessey and Danforth creeks drain basins 4 and 6, respectively. Bessey Creek discharges to the mouth of C-23, which in turn empties into the St. Lucie River. Danforth Creek discharges to the South Fork of the St. Lucie River Estuary. Basin 5 is generally landlocked, with a poor hydraulic connection to Bessey Creek. Inadequate conveyance in the drainage systems in these basins has frequently resulted in areas of inundation in flood-prone areas.

Tidal Area

There are three basins within the Tidal Area: 1) North Coastal, 2) Middle Coastal and 3) South Coastal. These basins are located in coastal St. Lucie and Martin counties. In general, these basins contain barrier islands, the Intracoastal Waterway and mainland beaches. Most of the surface water in these basins is tidal.

Groundwater Resources

The hydrogeology of south Florida is diverse. Within an individual aquifer, hydraulic properties and water quality may vary both vertically and horizontally. Because of this diversity, groundwater supply potential varies greatly from one place to another. It is the purpose of this section to identify the aquifers in the UEC Region, and describe their current usage and water producing capability.

Three major hydrogeologic units underlie the UEC Planning Area: the Surficial Aquifer System (SAS), the intermediate confining unit (low permeable sediments of the Hawthorn Group), and the Floridan Aquifer System (FAS), **Figure 9**. The SAS extends from land surface to the top of the intermediate confining unit and the intermediate confining unit extends to the top of the FAS. **Figure 10** shows the general geologic and hydrogeologic units in the UEC Planning Area. **Table 33** lists the groundwater systems, hydrogeologic units, average thicknesses and relative aquifer yields to each county in the UEC.

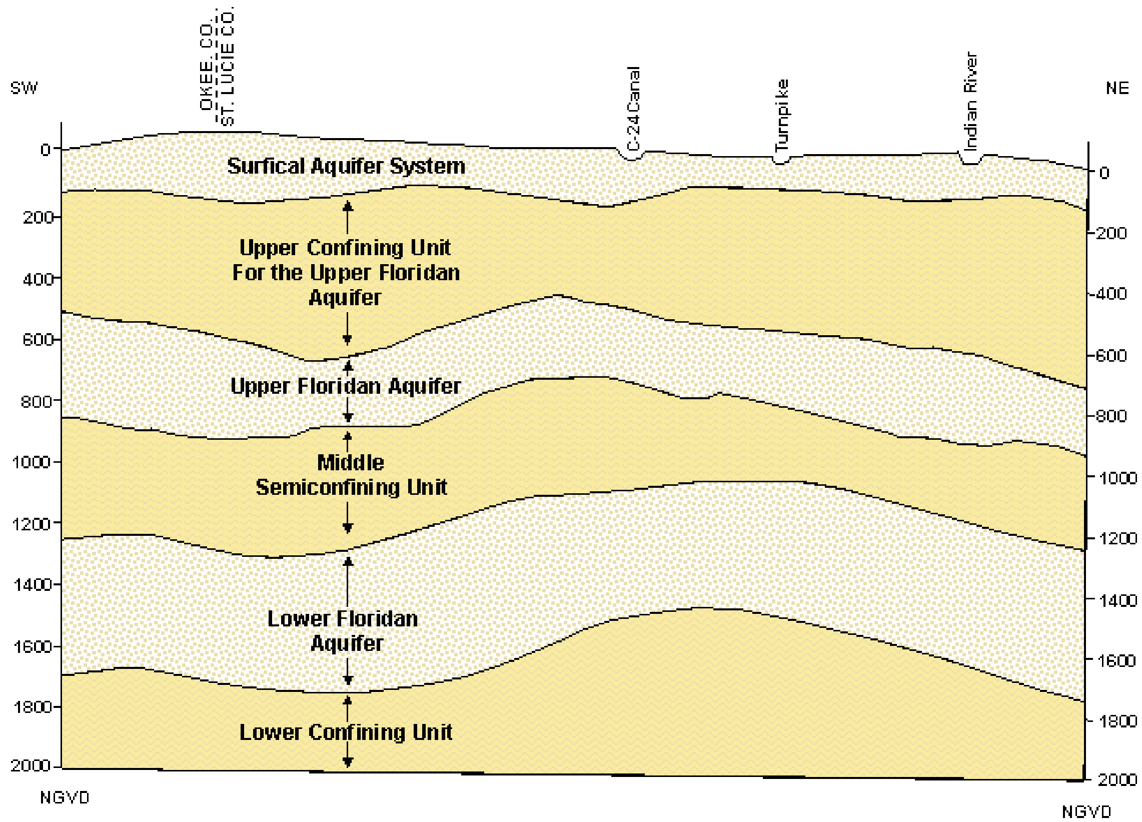


Figure 9. General Geologic and Hydrogeologic Units in the Upper East Coast.

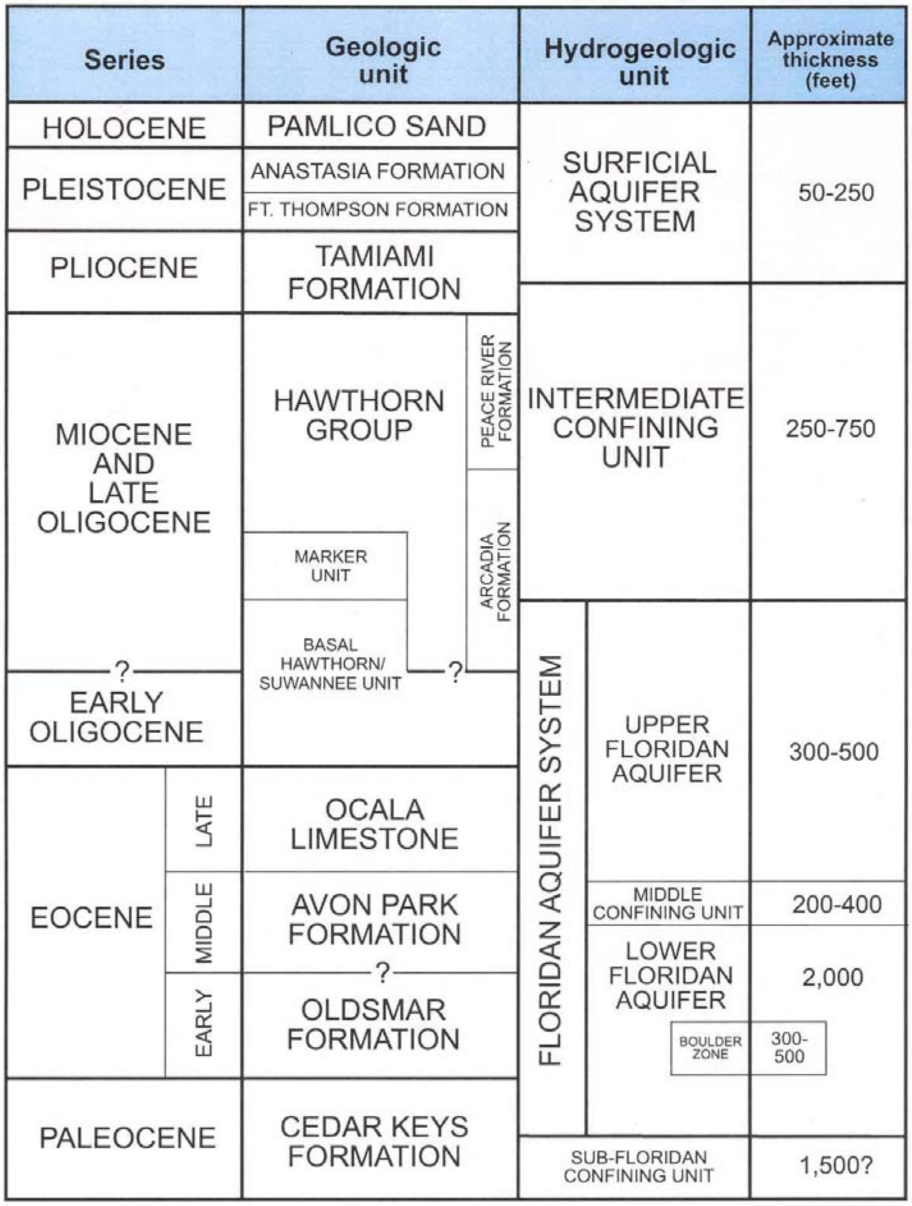


Figure 10. General Geologic and Hydrogeologic Units in the UEC (from Reese, 2002).

Table 33. Groundwater Systems in the Upper East Coast Region.

Aquifer System	Hydrogeologic Unit	Thickness (feet)	Aquifer Yield 1-Low 2-Moderate 3-High		
			Martin	St. Lucie	Okeechobee
Surficial Aquifer System	Surficial Aquifer	90–250 (10-180 in eastern Okeechobee Co.)	2	1-2	1
Intermediate Confining Unit	Hawthorn Group	400-700	1	1	1
Floridan Aquifer System	Upper Floridan Aquifer	500	3	3	2-3
	Middle Semi - Confining Unit		1	1	1
	Lower Floridan Aquifer		3	3	3

Surficial Aquifer System

The SAS is the principal source of water for urban uses, including potable water, within the UEC Planning Area. It includes all saturated rock and sediment from the water table to the top of the underlying intermediate confining unit. The SAS ranges in thickness from 50 to 250 feet in the UEC (Brown and Reece, 1979). Its lithology consists of quartz sand, silts, clay, shell beds, coquina, calcareous sandstone and shelly limestone. The geologic units that make up the aquifers are from youngest to oldest: the Pamlico sand (Pleistocene), the Anastasia formation (Pleistocene), the Fort Thompson formation (Pliocene), and possibly part of the Tamiami formation (Pliocene).

The SAS is generally unconfined to semi-confined (Adams, 1992). The permeability of the aquifer typically increases to the south and east in the UEC Planning Area (Butler and Padgett, 1995). Productivity and water quality in the aquifer also tend to improve from north to south and west to east. Throughout most of the UEC, water in the SAS meets national drinking water standards with respect to chloride, total dissolved solids (TDS), and sulfate concentrations (Lukasiewicz and Switanek, 1995).

Intermediate Confining Unit

Within the UEC Planning Area, the intermediate confining unit is comprised of the relatively impermeable sequence of phosphatic clays, silts and limestones of the Hawthorn Group. The top of the confining unit lies approximately -80 feet NGVD in the northwest corner of St. Lucie County. It dips gently to the southeast, reaching a maximum depth of more than -200 feet NGVD in southeastern Martin County. Thickness also varies, ranging from less than 300 feet in northern St. Lucie County, to more than 600 feet at the extreme southern end of the planning area. The intermediate confining unit does not yield significant quantities of water to wells. The permeability of the intermediate confining unit is low and it separates the overlying SAS from the underlying FAS.

Floridan Aquifer System

The FAS, which underlies all of Florida and portions of southern Georgia and Alabama, ranges in thickness from 2,700 to 3,400 feet within the UEC Planning Area. The top of the FAS lies around -300 feet NGVD in the northwest corner of the planning area, then dips to the southeast to more than -900 feet NGVD in southeast Martin County. **Figure 11** shows the elevation of the top of the FAS, which corresponds to the top of the basal Hawthorn/Suwannee unit. Parker *et al*. (1955) designated the FAS to include "parts of the middle Eocene (Avon Park and Lake City Limestone), upper Eocene (Ocala Limestone), Oligocene (Suwannee Limestone) and Miocene (Tampa Limestone, and permeable parts of the Hawthorn formation that are in hydrologic contact with the rest of the aquifer)."

Within the FAS, there are multiple permeable intervals, or producing zones, sandwiched between low permeability confining materials. The permeable intervals are associated with solution cavities and formational unconformities, the latter of which can be correlated over large areas. The FAS is divided into two aquifers based on the vertical occurrence of two highly permeable zones. These are the upper Floridan and lower Floridan Aquifers. They are separated by a low permeability interval named the middle semi-confining unit. The term lower Floridan, as it appears here, refers to the upper portion of the lower Floridan Aquifer. The following terminology and geologic description of the FAS was adopted from Lukasiewicz (1992).

The FAS is an important source of agricultural irrigation water, particularly in the northern portion of the planning area. The FAS, however, requires blending with surface water prior to irrigation. In addition, public water utilities must provide treatment to remove chlorides in order to supply potable uses. The quality of water in the FAS deteriorates to the south, increasing in hardness and salinity. Salinity also increases with depth, making the deeper producing zones less suitable for development than those near the top of the system.

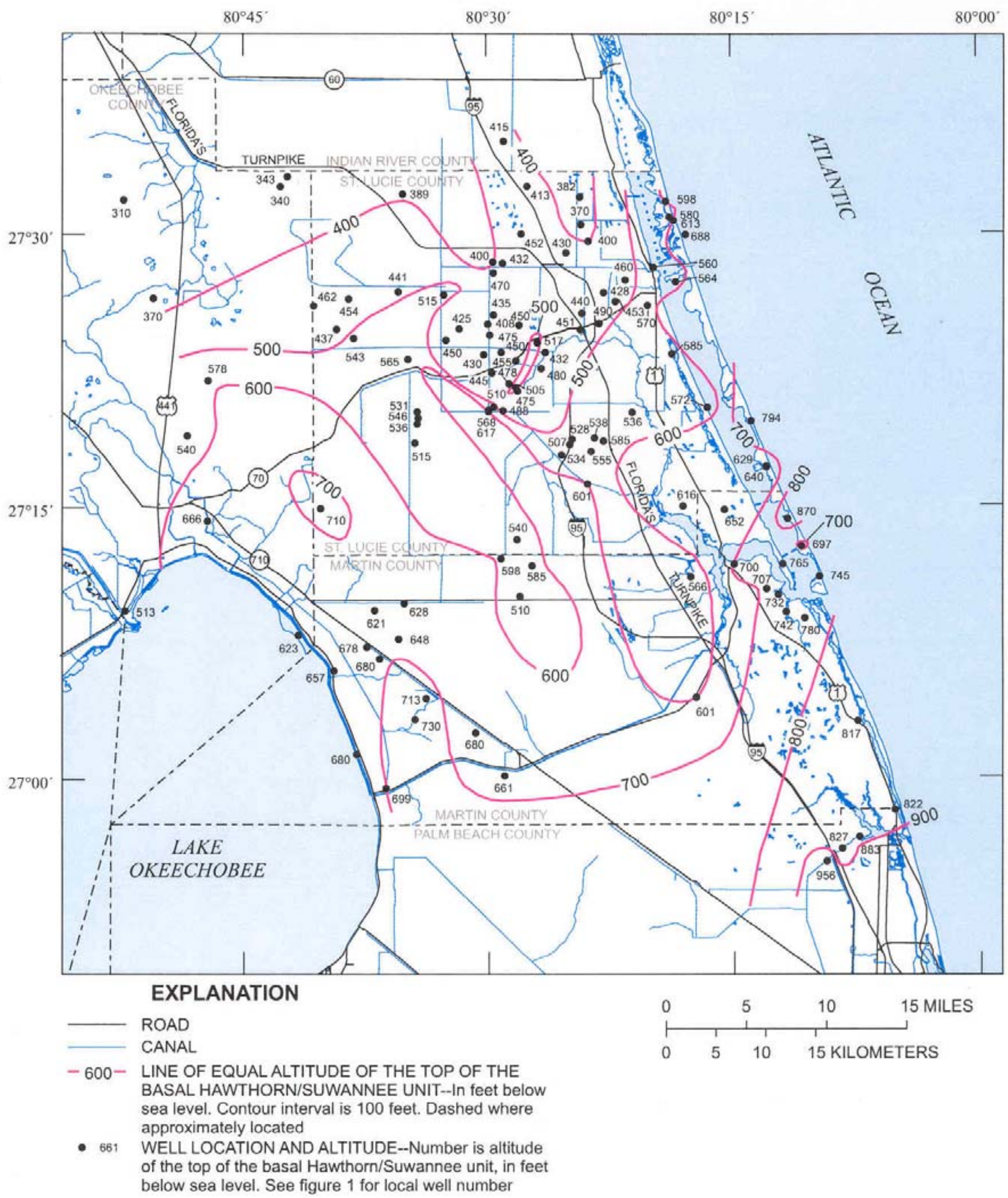


Figure 11. Elevation of the Top of the Floridan Aquifer System in Feet Below Sea Level (after Reese, 2002).

Upper Floridan Aquifer

The upper Floridan Aquifer (UFA) is the principal source of supply to users of the FAS in the UEC Planning Area. It is approximately 500 feet thick, and characterized by two distinct and continuous producing zones. These two zones occur along the unconformities, serving as the lithologic contacts between the Suwannee formation and the Ocala Group, and the Ocala Group and the Avon Park formation. There are also numerous high permeability zones created by solutioning and dolomitization (the replacement of calcium carbonate with magnesium carbonate). These zones are not stratigraphically controlled, and occur irregularly throughout the planning area.

The UFA is an important source of irrigation water for agriculture in St. Lucie County and to a lesser extent in Martin County. Floridan wells, which flow without pumping, produce large volumes of brackish water. Total dissolve solid (TDS) concentrations in UFA water average about 900 mg/L and increase toward the southeast to 3,000 mg/L in southeastern Martin County. Because of the salinity, ranchers and grove operators tend to discharge Floridan water into irrigation ditches, where it mixes with fresher surface water and groundwater from the SAS. This dilutes the brackish Floridan water to a level acceptable for agricultural irrigation, and allows growers to supplement their surface water supplies when availability is limited.

Where chlorides are sufficiently low, upper Floridan water can be blended with SAS water for use by public water supplies (i.e., Fort Pierce Utilities Authority). In most cases, however, desalination treatment is necessary to provide potable quality water. The City of Fort Pierce, Martin County Utilities and the Town of Jupiter, as well as numerous development communities along the coast, are using, or have immediate plans to use desalinated UFA water to supply their service areas. The productivity of the UFA is considerably greater than that of the SAS throughout most of the planning area, although a structural feature approximately aligned with the Intracoastal Waterway, results in reduced productivity along the coastal margin north of Vero Beach. Overall, chlorides are within a reasonable range for current desalination technologies. It is expected that, as the area continues to grow, use of the UFA for augmenting urban supply will increase.

Middle Semi-Confining Unit

The middle semi-confining unit, corresponding stratigraphically to the Avon Park Formation, is composed of chalky calcilucite interbedded with limestones and dolomites. Because few wells in the planning area fully penetrate this unit, data on its variability is limited. Data from a few test wells in the planning area place its thickness from 200 to 400 feet.

Lower Floridan Aquifer

The deeper producing zones of the FAS are associated with the Lake City Limestone, a hard, porous, crystalline dolomitic limestone, with stringers of chalky fossiliferous limestone.

There are two distinct flow zones within the upper part of the lower Floridan Aquifer (LFA), one at the contact between the Lake City Limestone and the Avon Park Formation, and a deeper one where the Lake City Limestone contacts the Oldsmar formation. In this document, these flow zones are referred to as lower Floridan Aquifer Production Zones 1 and 2. Borehole geophysical logs and drill stem tests performed at two test wells in the planning area indicate the permeability of the two zones is cavernous in nature. The zones are separated by approximately 250 feet of low permeability material.

The two producing zones may also be distinguished by a significant difference in water quality. Water samples collected from a test well in central St. Lucie County showed TDS concentrations between 1,100 to 1,200 parts per million (ppm) in the upper producing zone, and greater than 2,000 ppm in the lower zone.

Although very transmissive zones have been documented within the LFA, they are generally not used as supply sources within the UEC Planning Area due to the high salinity and mineral content of their water and higher drilling costs required to complete a well in this zone. An exception to this is in the Town of Jupiter wellfield, which has several wells completed in the LFA. This portion of the lower Floridan has been determined to have high potential for ASR due to its capacity for receiving and storing large quantities of injected water.

An area of extremely high transmissivity, known as the "boulder zone," occurs at the base of the LFA. In south Florida, the boulder zone has been used for disposal of treated wastewater effluent and reject water/concentrate from reverse osmosis water treatment facilities. A thick confining layer of dense limestones and dolomites prevents flow between the boulder zone and the transmissive zones at the top of the LFA. The base of the lower Floridan generally coincides with the top of the evaporate beds in the Cedar Keys Formation (Miller, 1986).

Surface Water/Groundwater Relationships

In the preceding sections, surface water and groundwater resources have been addressed as separate entities. In many ways, however, they are interdependent. The construction and operation of surface water management systems affect the quantity and distribution of recharge to the SAS. Although surface water management systems are a major source of water supply, in terms of interaction with groundwater, the systems within the planning area function primarily as aquifer drains. It is estimated that 19 percent of groundwater flow in Martin County is discharged into surface water bodies, while only one percent of aquifer recharge is derived from surface water sources. Surface water management systems also affect aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use or it may be lost to evapotranspiration (ET) or discharged to tide.

Although the FAS is not hydraulically connected to surface water within the planning area, FAS water is usually diluted with surface water to achieve an acceptable quality for agricultural irrigation. Consequently, surface water availability for dilution purposes can be a limiting factor on the use of FAS water.

WATER NEEDS OF COASTAL RESOURCES

St. Lucie Estuary

The St. Lucie Estuary is one of the largest brackish water bodies on the east coast of Florida and is a primary tributary to the southern Indian River Lagoon. The St. Lucie Estuary (SLE) is comprised of the North Fork, the South Fork and the middle estuary. The middle estuary extends east for approximately 5 miles until it meets the Indian River Lagoon (IRL), just before opening to the Atlantic Ocean at the St. Lucie Inlet. The SLE has been highly altered at both its landward and seaward ends.

The C&SF Flood Control Project has created some long-range problems. Freshwater discharges from the C-23, C-24, C-25 and C-44 canals to the SLE and IRL pose problems in maintaining a healthy estuarine system. High volume, prolonged fresh water releases from Lake Okeechobee via the C-44 Canal also have a dramatic effect on water quality and the health of the estuarine system. As fresh water is released, sediment from eroding canal banks and pollutants from stormwater runoff has negative effects on water quality in the St. Lucie River. Another problem associated with water releases from Lake Okeechobee is the drastic change in salinity levels within the SLE.

Maintenance of appropriate freshwater inflows is essential for a healthy estuarine system. Excessive changes in freshwater inflows to the estuary result in imbalances beyond the tolerances of estuarine organisms. The retention of water within upland basins for water supply purposes can reduce inflows into the estuary and promote excessive salinities. Conversely, the inflow of large quantities of water into the estuary due to flood control activities can significantly reduce salinities and introduce stormwater contaminants.

The Comprehensive Everglades Restoration Plan and possible modifications to the Lake Okeechobee Regulation Schedule will address freshwater discharges from Lake Okeechobee to the St. Lucie River via the C-44 Canal.

Indian River Lagoon

As the St. Lucie River's fresh water flows toward the St. Lucie Estuary, it becomes part of the Indian River Lagoon, the most biodiverse estuarine system in all of North America.

The Indian River Lagoon (IRL) is a series of three distinct, but interconnected, estuarine systems, which extend 156 miles from Ponce DeLeon Inlet in Volusia County southward to Jupiter Inlet in Palm Beach County on Florida's east coast. The northern portion of the lagoon is within the St. Johns River Water Management District (SJRWMD). The lagoon's southern section is located within the South Florida Water Management District (SFWMD) in St. Lucie, Martin and northern Palm Beach counties.

More than 4,000 species of plants and animals have been observed in the IRL. The lagoon supports multimillion-dollar fishing, clamming, tourism, agriculture and recreation industries.

Increasing industrial, agricultural, residential and commercial development have influenced the health of the IRL. The combined effects of wastewater and stormwater runoff, drainage, navigation, loss of marshland and development has influenced the lagoon’s water, sediment and habitat quality. The lagoon system has lost emergent wetlands through destruction and impoundment, isolating marsh and mangrove communities from the lagoon. The effects of these man-made changes have altered the timing (excess wet season flows, insufficient dry season flows), distribution, quality and volume of fresh water entering the lagoon. The estuarine environment is sensitive to freshwater releases, and these alterations have influenced the entire ecosystem. Extreme salinity fluctuations and ever-increasing inflows have contributed to changes in the structure of the communities within the estuary.

The SFWMD C-25 Canal and the Fort Pierce Farms Water Control District Canal (Number 1) discharge through Taylor Creek into the IRL at Fort Pierce. On outgoing tides these discharges exit the lagoon at the Fort Pierce Inlet; however, on incoming tides discharge water moves northward into the IRL. Salinity in this area of the IRL is reduced considerably as discharges continue, and the lowered salinities linger for days after the discharges have ceased.

The high biological diversity of the IRL is largely dependent upon interchange of species and individuals with the ocean. The Fort Pierce Inlet links these ecosystems together. The high diversity of fish in the IRL depends upon maintenance of relatively high salinities in the Fort Pierce Inlet and its vicinity. These higher salinities are typical when the stormwater canals are not discharging. The occurrence of lowered salinity influences the biodiversity of the Indian River.

The Comprehensive Everglades Restoration Plan (CERP) IRL – South Feasibility Study investigated options to alter the affects of the flow of surface waters through the existing regional flood control system to the St. Lucie River and Estuary and the IRL.

This study focused on making improvements to restore the environmental health of the receiving water bodies as well as the watershed, while maintaining the existing functionality of the flood control system.

The Final Indian River Lagoon – South Feasibility Study recommended a plan designed to reduce the impacts from the watershed runoff, while relying on the development of other CERP components that significantly reduce the number and frequency of high volume discharges from Lake Okeechobee through the C-44 Canal to the estuarine system.

The *Final Indian River Lagoon – South Project Implementation Report Public Notic*e was signed by the USACE in Atlanta in March 2004. The Project Implementation Report (PIR) will be submitted to the USACE Headquarters in Washington, D.C. for final review. Approvals are being sought to incorporate the Indian River Lagoon – South Project in the WRDA 2004. Construction could start as early as 2006, and be complete within six years, at an estimated cost of $1.21 billion.

Loxahatchee River

The diverse natural ecosystems and hydrology found within the Loxahatchee River's watershed are unique, beginning with the Atlantic Ocean, which feeds its marine waters inshore through the Inlet at Jupiter. Just inshore, the river broadens into the aquatic preserves of the IRL. Continuing westerly and upstream, the water systems include vast wetlands and the Loxahatchee Slough. The Loxahatchee River, Florida's first federally designated “National Wild and Scenic River,” winds its way through Jonathan Dickinson State Park.

In contrast to concerns of freshwater encroachment in estuarine systems, the Loxahatchee River has been significantly affected by the creation of the Jupiter Inlet. Prior to development, the Loxahatchee River watershed was nearly level, poorly drained land that was subject to frequent flooding. With the construction of the C-18 Canal and installation of drainage projects for agricultural and urban development, water tables have been lowered and the amount of fresh water available to the Loxahatchee River has been reduced.

These changes have significantly altered natural flow patterns allowing salt water to move further up the river resulting in the displacement of freshwater wetland species by estuarine species. The effects on regional hydrology, river flow, estuary hydrodynamics and river vegetation communities are documented. Over a century of water control and structural modifications to the Loxahatchee system have led to changes in the quality, quantity, timing and distribution of flows delivered to the river and estuary, resulting in hydrologic and ecologic changes to the system. Salinity impacts observed within the river occurred in association with construction and dredging of Jupiter Inlet in 1947 and subsequent upstream navigational improvements over time. Drainage and land development activities have changed the timing and distribution of flows from the watershed to the river, producing large discharges during wet periods and extended periods of little or no discharge during extreme dry periods.

A minimum flow and level was established for the Northwest Fork of the Loxahatchee River in 2002 and restoration efforts are underway. Implementation of projects in the 2002 Northern Palm Beach County Comprehensive Water Management Plan and recommendations in the 2000 Lower East Coast Regional Water Supply Plan are beginning to address freshwater flows to the Loxahatchee River. Approximately 44,800 acre-feet of storage have been purchased in the L-8 Reservoir, the G-160 Loxahatchee Slough Structure in northeastern Palm Beach County has been completed and construction of the G-161 Northlake Boulevard Structure has begun. In addition to structural improvements that will benefit environmental water supply, the following efforts will further address freshwater timing and flow to this system: water reservations for the Northwest Fork of the Loxahatchee River; development of a restoration plan; completion of the Comprehensive Everglades Restoration Plan North Palm Beach County Part 1 Project Implementation Report; and establishment of minimum flows and levels for the tributaries to the Northwest Fork of the Loxahatchee River.

Salinity Envelope Concept

The SFWMD has used data from the following sources to identify a favorable range of inflow and related salinity, which would be conducive to growth and survival of juvenile marine fish and shellfish, oysters and submerged aquatic vegetation in the SLE: research on fish and shellfish; monthly salinity data collected over many decades; and results from studies of similar estuaries throughout the world (SJRWMD and SFWMD 2002). This favorable range of flows, from 350 to 2000 cfs, is referred to as the “Salinity Envelope.” The “Salinity Envelope” of was established for the SLE based on providing preferred salinities for oysters and submerged aquatic vegetation in areas within the estuary where ‘healthy’ populations of these communities could exist. These populations can persist as long as the favorable ranges of flows and salinity are not violated beyond the frequency that is attributed to natural variation of flows from the watershed (Haunert and Konyha, 2000).

Coastal Resources Water Needs Goal

A long-term goal of the SFWMD is to develop coupled watershed-estuarine models that can be used to: (1) estimate historical runoff patterns that occurred prior to human intervention; and (2) evaluate the effects of watershed alterations on receiving waters. Such alterations include changes in canal discharge or point of discharge, operation of storage facilities, impacts of filter marshes and best management practices (BMPs) on water quality, and operation of coastal structures. These management tools can be used to explore creative ways to meet minimum flows and levels (MFLs) and pollution load reduction goals (PLRGs), to test operational criteria for CERP infrastructure, to define environmentally sensitive operating procedures for existing water management schedules and to establish restoration goals.

CHAPTER 8
Lower West Coast

PLAN BOUNDARIES

The Lower West Coast (LWC) Planning Area includes all of Lee County, most of Collier and Hendry counties, portions of Charlotte and Glades counties and portions of mainland Monroe County (**Figure 1**). The portions of counties partially within the LWC Planning Area are referred to as the Collier County Area, Hendry County Area, Charlotte County Area, Glades County Area and Monroe County Area. The boundaries of the LWC Planning Area generally reflect the drainage patterns of the Caloosahatchee River Basin and the Big Cypress Swamp. The northern boundary corresponds to the drainage divide of the Caloosahatchee River, which is generally the SFWMD/Southwest Florida Water Management District (SWFWMD) jurisdictional boundary in Charlotte County, while the eastern boundary delineates the divide between the Big Cypress Swamp and the Everglades system. The area east of this divide is in the Lower East Coast (LEC) Planning Area.

PHYSICAL FEATURES

Geography and Climate

The LWC Planning Area covers approximately 5,129 square miles. Average seasonal temperatures range from 64.3 degrees in January to 82.6 degrees in August. Nearly two-thirds of annual rainfall occurs during the May to October wet season.

Physiography

The SFWMD is comprised of two major basins, the Okeechobee and the Big Cypress Basin. A large part of the LWC Planning Area lies within the boundary of the Big Cypress physiographic province. This region, which is flat and has large areas with solution-riddled limestone at the surface, drains to the coastal marshes and mangrove swamps of the Ten Thousand Islands. The only major waterway in the LWC Planning Area other than the Caloosahatchee River is the system of canals and water control structures in western Collier County. This system is monitored, controlled and managed by the Big Cypress Basin. The physiography of south Florida is discussed in further detail in *"Environments of South Florida: Present and Past II"* (Gleason, 1984).

WATER RESOURCES AND SYSTEM OVERVIEW

Regional Hydrologic Cycle

The main components of the hydrologic cycle are precipitation (and the resulting infiltration); evapotranspiration (and the resulting withdrawal); surface water inflow and outflow; and groundwater flow.

Precipitation and Evapotranspiration

The average annual precipitation in the LWC Planning Area is approximately 52 inches. Nearly two-thirds of the rainfall occurs during the six-month wet season from May through October.

Surface Water Inflow and Outflow

Most surface water in the LWC Planning Area is derived from rainfall. The exception to this is the Caloosahatchee River Canal (C-43), which also receives water from Lake Okeechobee. Historic flowways in the region were the natural drainage features consisting of a series of flat wetlands or swamps connected by shallow drainage ways or sloughs that were divided by low ridges. These features were dry for a portion of the year, and overtopped by water in periods of seasonal high rainfall. The majority of the canals in the LWC Planning Area were constructed as surface water drainage systems rather than for water supply purposes. The C-43 Canal is the only major canal used for water supply and it is maintained by releases from Lake Okeechobee. The amount of stored water is of critical importance to both the natural ecosystems and the developed areas in the LWC Planning Area. Management of surface water storage capacity involves balancing two conflicting conditions. When there is little water in storage, drought conditions may occur during periods of deficient rainfall. Conversely, when storage is at capacity, flooding may occur due to excessive rainfall, especially during the wet season. Management of surface water systems is one of the main factors affecting movement of water through the regional hydrologic cycle.

Groundwater Flow

Three aquifer systems, the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS) and the Floridan Aquifer System (FAS), underlie the LWC Planning Area. Rainfall is the main source of recharge to the SAS. The IAS is partially recharged from the SAS. The FAS receives its recharge from outside the LWC Planning Area.

Surface Water Resources

Prior to development, nearly level, poorly drained lands subject to frequent flooding characterized most of the LWC Planning Area. The natural surface drainage systems included large expanses of sloughs and marshes, such as Telegraph Cypress Swamp, Corkscrew Swamp, Flint Pen Strand, Camp Keais Strand, Six Mile Cypress Slough, Okaloacoochee Slough and Twelve Mile Slough.

Lakes, Rivers, Canals and Drainage Basins

Surface water bodies in the LWC Planning Area include lakes, rivers and canals, which provide storage and conveyance of surface water. Lake Trafford and Lake Hicpochee are the two largest lakes within the LWC Planning Area, but neither lake is considered a good source of water supply.

The Caloosahatchee River is the most important source of surface water in the region and extends across seven of the ten drainage basins in the LWC Planning Area. The river is supplied by inflows from Lake Okeechobee and runoff from within its own basin. The freshwater portion of the river (C-43) extends eastward from the Franklin Lock and Dam (S-79) towards Lake Okeechobee and the cities of LaBelle and Moore Haven. West of S-79, the river mixes freely with estuarine water as it empties into the Gulf of Mexico.

The remaining rivers and canals in the LWC Planning Area drain into Estero Bay, the Caloosahatchee River or the Gulf of Mexico. The majority of canals were constructed as surface water drainage systems rather than for water supply purposes. The C-43 Canal is the only major canal used for water supply and it is maintained by releases from Lake Okeechobee.

Drainage Basins

The LWC Planning Area is divided into 10 major drainage basins according to their respective hydrologic characteristics. These basins are the: 1) North Coastal Basin; 2) Tidal Caloosahatchee Basin; 3) Telegraph Swamp Basin; 4) West Caloosahatchee Basin; 5) East Caloosahatchee Basin; 6) C-21 Basin; 7) S-236 Basin; 8) Estero Bay Basin; 9) West Collier Basin; and 10) East Collier Basin. The West Collier and East Collier basins have extensive wetland systems.

The LWC Planning Document recommended that the District identify opportunities to evaluate the feasibility of using the Caloosahatchee River as a seasonal source of supply. The *Caloosahatchee Water Management Plan* (CWMP), completed in April 2000, addresses availability of water from the river. In addition, the Southwest Florida Feasibility Study, underway, is analyzing the natural system restoration projects in the region.

North Coastal Basin

The North Coastal Basin is in southwestern Charlotte County and northwestern Lee County. There are numerous creeks within this basin. The basin drains via overland flow from the Fred C. Babcock/Cecil M. Webb Wildlife Management Area in Charlotte County into the Gator Slough watershed within northwestern Lee County. Most of this basin drains through the Gator Slough Canal into the Cape Coral Canal System. Improvements were made in 1998 to divert water to Cape Coral for direct use or recharge.

Tidal Caloosahatchee Basin

The Tidal Caloosahatchee Basin extends on both sides of the saltwater portion of the Caloosahatchee Basin, northerly into Charlotte County. Numerous creeks drain into the Caloosahatchee River in this basin. These creeks are tidally influenced and are not suitable as a major source of surface water withdrawal. The Lee County Interim Surface Water Management Plan (Johnson Engineering *et al*., 1990) recommends putting weirs in several of the creeks to maintain water levels in the dry season. The report suggests that Trout Creek and the channelized portion of the Orange River have a potential for water supply. Trout Creek receives drainage from the Fred C. Babcock/Cecil M. Webb area via sheet flow and a large canal; placing a weir in the creek would enhance its water supply potential. In the Lehigh Acres area, the weirs in Able Canal (the channelized portion of the Orange River) provide recharge to the area. The East County Water Control District is modifying internal weirs to retain more water on-site for groundwater recharge. A minimum flow and level for the Caloosahatchee River and Estuary was established in 2001, with further modifications in process.

Telegraph Swamp Basin

The Telegraph Swamp Basin extends from Charlotte County southward to the Caloosahatchee River. The major feature of this basin is the Telegraph Cypress Swamp, which drains via sheet flow into Telegraph Creek in Lee County. Since this is a large watershed (approximately 92 square miles) with sheet flow discharge, there is a potential for this basin to be a good recharge area (Johnson Engineering *et al*., 1990).

West and East Caloosahatchee, C-21 and S-236 Basins

The West and East Caloosahatchee, C-21 and S-236 basins extend along the freshwater portion of the Caloosahatchee River (C-43 Canal), from S-79 (Franklin Lock and Dam) to S-77 at Lake Okeechobee. The basins include parts of Lee, Collier, Hendry, Glades and Charlotte counties. The C-43 Canal is the major surface water resource within these basins. The primary purpose for the canal is to provide relief for regulatory releases of excess water from Lake Okeechobee. In the East Caloosahatchee Basin, Lake Hicpochee was severely impacted by the construction of the C-43 Canal. The canal was constructed through the lake's center, which resulted in lower lake water levels. The C-43

Canal provides drainage for numerous private drainage systems and local drainage districts within the combined drainage basins.

The C-43 Canal also provides water for agricultural irrigation projects within the basins and public water supply for the city of Fort Myers and Lee County. There are three structures (S-77, S-78 and S-79) providing navigation and water control in the C-43 Canal. These structures serve to control the water stages in C-43 from Lake Okeechobee (S-77) to Franklin Lock (S-79). Water levels upstream of S-78 are maintained at approximately 11 feet NGVD, and 3 feet NGVD downstream. The S-79 Structure also serves as a saltwater barrier. The operation schedule for these structures is dependent on rainfall conditions, agricultural practices, the need for regulatory releases from Lake Okeechobee and the need to provide water quality control for the public water supply facilities.

Estero Bay Basin

In the Estero Bay Basin in southern Lee County, there is a two-fold water management problem. Overdrainage is a problem in areas due to development. Conversely, lack of conveyance in other areas results in flooding. The basins include Hendry Creek, Mullock Creek/Ten Mile Canal/Six Mile Cypress Slough, Kehl Canal/ Imperial River, Estero River and Spring Creek. These waterways, with the exception of Ten Mile Canal and Kehl Canal, are all tidally influenced to some degree.

Several waterworks projects have been completed, or are underway, to increase water levels in the western part of the basin and to protect the water resources against saltwater intrusion (Hendry Creek has a saltwater barrier and weirs in Ten Mile Canal have been raised to increase the water levels within Six Mile Cypress Slough). Johnson Engineering (1990) concluded that the Estero Bay Basin does not have a major source of surface water available for water supply. However, because the basin has good recharge areas, saltwater barriers (weirs), could be used to increase water levels within the basin for recharge.

The Estero River east of U.S. 41 has slow conveyance and is considered a good recharge area, as is the Imperial River east of I-75. The Kehl Canal is connected to this river and drains the water levels within this basin in the dry season. The District and Lee County cost-shared the replacement of the existing temporary Kehl Canal Weir, with a permanent structure containing two screw gates for water management. This weir increases water levels in the east Bonita area (a major recharge area). The new weir was designed to have the flexibility to add a cap to the weir structure to increase the water level to 12–13 feet NGVD for additional recharge capabilities in the area.

West Collier Basin

The West Collier Basin extends from State Road 29 westward to the Gulf of Mexico and northward to the Lee County border, and includes part of Hendry County. The basin does not have a major source of surface water for year round water supply. Lake Trafford, in the northern section of the basin, has a drainage area of approximately 30 square miles. The lake is relatively small (2.3 square miles) and is not considered a significant source of water storage for the region.

The Gordon and Cocohatchee rivers are the two remnant natural rivers in this basin. Both of these rivers are tidally influenced and connect to the canal system within this basin. This basin flows into the Gulf of Mexico near the Ten Thousand Islands. This canal system, operated and managed by the Big Cypress Basin Board (BCBB), serves primarily as a drainage network. The BCBB has retrofitted many old weirs and constructed new water control structures in these canals to prevent overdrainage of the basin. Since the primary source of water for this system is rainfall, the canals have little or no flow during the dry season.

The West Collier Basin has extensive wetland systems. These systems include the Corkscrew Regional Ecosystem Watershed (CREW), Fakahatchee Strand State Preserve and the Collier-Seminole State Park. An assessment of the area was completed in September 1993. The assessment indicated that wellfield development and/or aquifer augmentation could affect the wetlands within the CREW boundaries. The assessment recommends detailed three-dimensional analyses prior to any proposed wellfield development.

East Collier Basin

The East Collier Basin extends from State Road 29 eastward to the LWC Planning Area boundary, north approximately 3 miles into southern Hendry County and south into Monroe County. Sheet flow from this basin flows south into the Everglades National Park and the Gulf of Mexico. The Big Cypress National Preserve forms most of this basin. There are no major rivers or major sources of surface water for year-round water supply use in this basin.

Groundwater Resources

Three major aquifer systems underlie southwestern Florida, the Surficial, Intermediate and Floridan Aquifer Systems as shown in the west to east cross section in **Figure 12.** These aquifer systems are composed of multiple, discrete aquifers separated by low permeability “confining” units. A generalized illustration of the geology and hydrogeology of southwestern Florida is given in **Figure 13** (Reese, 2000).

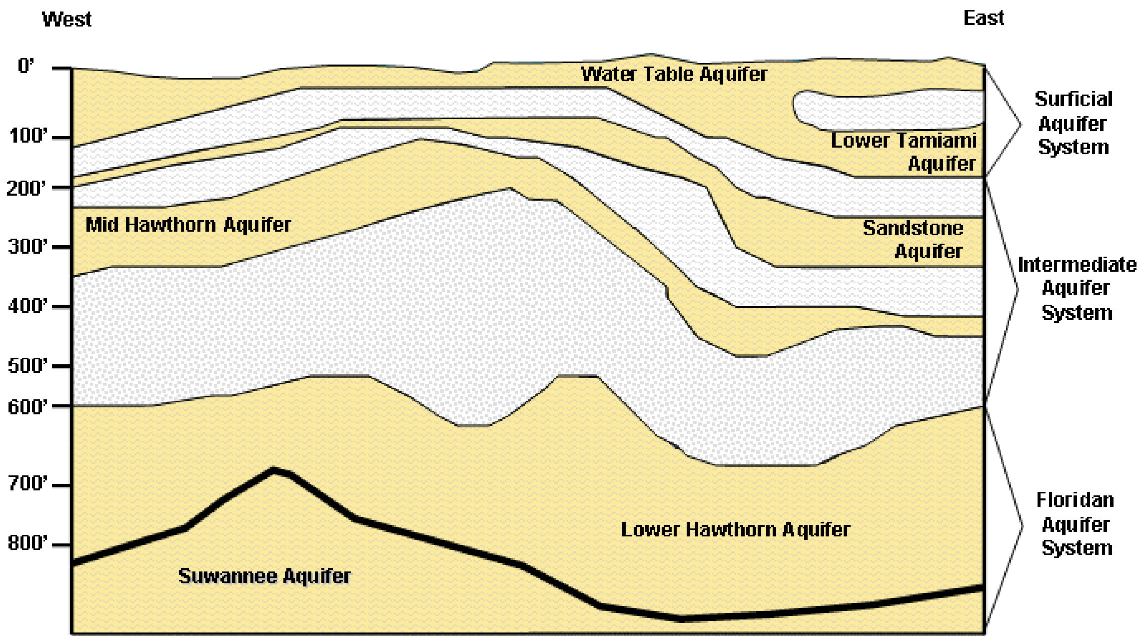


Figure 12. Generalized Cross-Section of the Lower West Coast.

Series		Geologic Unit		Approximate thickness (feet)	Lithology
HOLOCENE TO PLIOCENE		UNDIFFERENTIATED		0-70	Quartz sand, silt, clay, and shell
HOLOCENE TO PLIOCENE		TAMIAMI FORMATION		0-175	Silt, sandy clay, micritic limestone, sandy, shelly limestone, calcereous sand-stone, and quartz sand
MIOCENE AND LATE OLIGOCENE		HAWTHORN GROUP	PEACE RIVER FORMATION	50-400	Interbedded sand, silt, gravel, clay, carbonate, and phosphatic sand
MIOCENE AND LATE OLIGOCENE		HAWTHORN GROUP	ARCADIA FORMATION	400-550	Sandy limestone, shell beds, dolomite, phosphatic sand and carbonate, sand, silt, and clay
EARLY OLIGOCENE		SUWANNEE LIMESTONE		0-600	Fossiliferous, calcarenitic limestone
EOCENE	LATE	OCALA LIMESTONE		0-400	Chalky to fossiliferous, calcarenitic limestone
EOCENE	MIDDLE	AVON PARK FORMATION		900-1,200	Fine-grained, micritic to fossiliferous limestone, dolomitic limestone, dense dolomite, and gypsum
		?		?	
EOCENE	EARLY	OLDSMAR FORMATION		800-1,400	Fine-grained, micritic to fossiliferous limestone, dolomitic limestone, dense dolomite, and gypsum
PALEOCENE		CEDAR KEYS FORMATION		500-700	Dolomite and dolomitic limestone
PALEOCENE		CEDAR KEYS FORMATION		1,200 ?	Massive anhydrite beds

Hydrogeologic unit			Approximate thickness (feet)	
SURFICIAL AQUIFER SYSTEM	WATER-TABLE AQUIFER		20 -100	
SURFICIAL AQUIFER SYSTEM	CONFINING BEDS		0-60	
SURFICIAL AQUIFER SYSTEM	LOWER TAMIAMI AQUIFER		25-160	
INTERMEDIATE AQUIFER SYSTEM	CONFINING UNIT		20-100	
INTERMEDIATE AQUIFER SYSTEM	SANDSTONE AQUIFER		0 -100	
INTERMEDIATE AQUIFER SYSTEM	CONFINING UNIT		10-250	
INTERMEDIATE AQUIFER SYSTEM	MID-HAWTHORN AQUIFER		0-130	
INTERMEDIATE AQUIFER SYSTEM	CONFINING UNIT		100-400	
FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER	LOWER HAWTHORN PRODUCING ZONE	700-1,200	0-300
FLORIDAN AQUIFER SYSTEM	MIDDLE CONFINING UNIT		500-800	
FLORIDAN AQUIFER SYSTEM	LOWER FLORIDAN AQUIFER	BOULDER ZONE	1,400-1,800	400
	SUB-FLORIDAN CONFINING UNIT		1,200?	

Figure 13. Generalized Geology and Hydrogeology of Southwestern Florida (after Reese, 2000)

Within an individual aquifer, hydraulic properties (i.e., ability to yield water to wells) and water quality may vary both vertically and horizontally. Because of this diversity, groundwater supply potential varies greatly from one place to another. **Table 34** lists the aquifer systems, hydrogeologic units, average thickness and aquifer yields in the LWC Planning Area. It is the purpose of this section to identify the aquifers in the LWC Region and describe their characteristics.

Table 34. Groundwater Systems in Lower West Coast.

Aquifer System	Hydrogeologic Unit	Thickness (feet)	Aquifer Yield 1-Low 2-Moderate 3-High				
			Charlotte	Glades	Lee	Hendry	Collier
Surficial Aquifer System	Water Table Aquifer Confining Unit Lower Tamiami Aquifer	20-100 0-60 0-160	1	2	2	2	3
Intermediate Aquifer System	Sandstone Aquifer Confining Unit Mid-Hawthorn Aquifer	0-100 10-250 80-110	2	2	2	2	3
Floridan Aquifer System	Lower Hawthorn Aquifer/ Upper Floridan Aquifer	700-1,200	3	3	3	3	3
	Confining Unit	500-800	1	1	1	1	1
	Lower Floridan Aquifer	1,400-1,800	2	2	2	2	2

Surficial Aquifer System

The Surficial Aquifer System (SAS) consists of, in descending order, the Water Table Aquifer, confining beds and the lower Tamiami Aquifer of Holocene to Pliocene age. The thickness of the system ranges from about 200 feet in southwest Collier County to less than 25 feet in northern Lee County (Reese, 2000). The SAS is recharged primarily by precipitation, seepage from canals and other surface water bodies and upward leakance from the Intermediate Aquifer System (IAS).

Water Table Aquifer

The Water Table Aquifer is comprised of sediments from the land surface to the top of the Tamiami confining beds. Within Lee County, several major public water supply wellfields, all located in areas where the confining beds are absent, pump water from the Water Table Aquifer. The aquifer also furnishes irrigation water for many uses, including vegetables, berries, melons, nurseries and landscape irrigation. In Hendry

County, the Water Table Aquifer is generally used only where no suitable alternative is available. It may yield copious quantities of water in isolated areas. It produces good quality water, except in areas near LaBelle and parts of the coast where high concentrations of chlorides and dissolved solids are found. Some isolated areas also exist with high iron concentrations.

Lower Tamiami Aquifer

The lower Tamiami Aquifer is a major water producer in most of the LWC and supplies water to several wellfields, agricultural interests and domestic self-suppliers in the region. Because of the large demands on the aquifer, it has been endangered by saltwater intrusion on the coast, and is frequently included in water shortage declarations.

Recharge and Discharge Areas

The construction and operation of surface water management systems affect the quantity and distribution of recharge to the SAS. Surface water management systems within the LWC Planning Area function primarily as aquifer drains, since undrained, ambient groundwater levels generally exceed surface water elevations within the LWC Planning Area. The Caloosahatchee River and the Gulf of Mexico act as regional groundwater discharge points. Groundwater seepage represents 47 percent of the inflow to the Caloosahatchee River. During the wet season, after a rain event some recharge to the SAS may occur from drainage canals, small lakes, like Lake Trafford and low-lying areas. Surface water management systems also influence aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use, it may be lost to evapotranspiration or discharged to tide.

Intermediate Aquifer System

The Intermediate Aquifer System (IAS) consists of those units overlying and confining the Floridan Aquifer System and underlying the SAS. It consists of three relatively impermeable confining units between the sandstone and mid-Hawthorn aquifers and lies within the Hawthorn Group (Oligocene to Pliocene age). Recharge to the IAS occurs through upward leakance from the Floridan Aquifer System and through downward leakance from the SAS (Bush and Johnson, 1988).

The Sandstone Aquifer has variable thickness. On average, it is approximately 100 feet near Immokalee and portions of central Lee County. The productivity of the Sandstone Aquifer is highly variable. It provides all of the water used by several wellfields in the region. In western Hendry County, where the lower Tamiami Aquifer is absent, the Sandstone Aquifer is an important source of water for agricultural irrigation. However, it is not capable of supporting large-scale agricultural operations in most areas. Only marginally acceptable for potable uses in Hendry and Collier counties due to salinity, water from the Sandstone Aquifer is suitable primarily for irrigation purposes, with the exception of the LaBelle area, where flowing Floridan wells have contaminated the water.

Although present throughout the LWC Planning Area, the mid-Hawthorn Aquifer is not always productive. Its thickness is variable and relatively thin (it rarely exceeds 80 feet). This variability, combined with the presence of interbedded low permeability layers, results in low productivity of the aquifer. In addition to low productivity, the aquifer experiences degradation in water quality as it dips to the south and east, yielding only saline water in much of the LWC Planning Area.

The mid-Hawthorn Aquifer is used for domestic self-supply in those areas of Cape Coral not served by city water and for small water utilities north of the Caloosahatchee River. Elsewhere the aquifer is used only occasionally for agricultural irrigation.

Floridan Aquifer System

The Floridan Aquifer System (FAS) underlies all of Florida and portions of southern Georgia and Alabama. The top of the FAS coincides with the top of a vertically continuous permeable carbonate sequence (SE Florida Geologic Ad Hoc Committee, 1986) and is found between 600 to 1,000 feet below land surface (bls) in the region. It contains several thin, highly permeable, water bearing zones, which define the upper, middle and lower Floridan Aquifers. The upper Florida Aquifer includes the lower part of the Hawthorn Group, Suwanee limestone, Ocala limestone and upper part of the Avon Park Formation as shown in **Figure 13**. Production zones in the lower part of the Hawthorn Group and upper part of the Avon Park Formation are not always present. The upper Floridan Aquifer consists of several thin water bearing zones interlayered with thick zones of much lower permeability. It contains brackish (not saline) water and has potential as a water supply source through reverse osmosis or aquifer storage and recovery (ASR). Although it is the principal source of water in Central Florida, the FAS yields only nonpotable water throughout most of the LWC Planning Area. Salinity and hardness of water in the FAS increases from north to south and vertically with depth.

The lower Floridan Aquifer (LFA) is a highly permeable, fractured and/or highly solutioned, crystalline brown dolomite sandwiched between low permeability carbonate confining units. The base of the LFA ranges between 3,700 to 4,100 feet bls (Miller, 1986). The middle portion of the LFA contains a highly transmissive cavity and/or fracture-riddled dolomite known as the "boulder zone," typically about 3,000 feet bls. The boulder zone lies well beneath the saltwater interface; therefore, water in it is typically more saline than the ocean. It is highly cavernous and/or fractured, has extremely high transmissivity and is found in a section of rock approximately 400 feet thick (Reese, 2000). In some areas of south Florida, the boulder zone is used as a place to dispose (through pumping downhole) treated wastewater effluent and/or residual brines resulting from the desalination process. There is continued controversy over where the disposed fluids ultimately end up.

Water Quality

Water in the upper Floridan Aquifer is brackish and salinity increases with depth. Desalination technological improvements have made treatment of water from the FAS (and the lower Hawthorn Aquifer) more feasible and cost-effective where chloride concentrations are not prohibitively high. Currently, several utilities obtain source desalination water from the lower Hawthorn or upper Floridan Aquifers. Elsewhere, the upper Floridan Aquifer (UFA) supplies only a few agricultural irrigation wells. Efficiencies in the desalination treatment technology will likely cause the FAS to be increasingly utilized to satisfy growing populations and demand in the LWC Planning Area. Aquifer storage and recovery (ASR) is another attractive emerging technology likely to increase future use of the Floridan Aquifer in order to help meet growing water demands. In concept, ASR is simply the underground storage (through injection) of excess wet season rainfall and runoff. The Floridan Aquifer may be thought of as a universal potential underground reservoir. The hydrologic characteristics of the Floridan Aquifer are ideally suited for storing and recovering large volumes of stored water. The FDEP regulates all injection wells in Florida.

Surface Water/Groundwater Relationships

The construction and operation of surface water management systems affect the quantity and distribution of recharge to the SAS. Surface water management systems within the LWC Planning Area function primarily as aquifer drains, since undrained, ambient groundwater levels generally exceed surface water elevations within the LWC Planning Area. The Caloosahatchee River and the Gulf of Mexico act as regional groundwater discharge points. Groundwater seepage represents 47 percent of the inflow to the Caloosahatchee River. During the wet season, after a rain event some recharge to the SAS may occur from drainage canals, small lakes, like Lake Trafford and low-lying areas. Surface water management systems also affect aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use or it may be lost to evapotranspiration or discharged to tide.

WATER NEEDS OF COASTAL RESOURCES

Maintenance of appropriate freshwater inflows is essential for a healthy estuarine system. Preliminary findings indicate that inflows to the Caloosahatchee Estuary ideally should have mean monthly values between 300 cfs and 2,801 cfs. The mean daily flows range from 0 cfs to more than 13,652 cfs (Chamberlain *et al*., 1995). Excessive changes in freshwater inflows to the estuary result in imbalances beyond the tolerances of estuarine organisms. The retention of water within upland basins for water supply purposes can reduce inflows into the estuary and promote excessive salinities. Conversely, the inflow of large quantities of water into the estuary due to flood control activities can significantly reduce salinities and introduce stormwater contaminants. In addition to the immediate impacts associated with dramatic changes in freshwater inflows, long-term cumulative changes in water quality constituents, water clarity, or rates of sedimentation may also adversely affect the estuarine community.

Estuarine biota is well adapted to natural seasonal changes in salinity. The temporary storage and concurrent decrease in velocity of floodwaters within upstream wetlands aids in controlling the timing, duration and quantity of freshwater flows into the estuary. Upstream wetlands and their associated groundwater systems serve as freshwater reservoirs for the maintenance of base flow discharges into the estuaries, providing favorable salinities for estuarine biota. During the wet season, upstream wetlands provide pulses of organic detritus, which are exported down stream to the brackish water zone. These materials are an important link in the estuarine food chain.

Estuaries are important as nursery grounds for many commercially important fish species. Many freshwater wetland systems in the LWC Planning Area provide base flows to extensive estuarine systems in Lee, Collier and Monroe counties. Wetlands as far inland as the Okaloacoochee Slough in Hendry County contribute to the base flows entering some of these estuarine systems. Maintenance of these base flows is crucial to propagation of many fish species that are the basis of extensive commercial and recreational fishing industries.

The estuarine environment is sensitive to freshwater releases and disruption of the volume, distribution, circulation and temporal patterns of freshwater discharges could place severe stress on the entire ecosystem. Such salinity patterns affect productivity, population distribution, community composition, predator-prey interactions and food web structure in the inshore marine habitat. In many ways, salinity is a master ecological variable that controls important aspects of community structure and food web organization in coastal systems. Other aspects of water quality, such as turbidity, dissolved oxygen content and nutrient loads and toxins affect functions of these areas.

CHAPTER 9
Lower East Coast

PLAN BOUNDARIES

The Lower East Coast (LEC) Planning Area covers approximately 10,489 square miles and includes essentially all of Miami-Dade, Broward and Palm Beach counties, most of Monroe County and eastern portions of Hendry and Collier counties (**Figure 1**). The entire Lake Okeechobee Service Area, which includes parts of four additional counties, Martin, Okeechobee, Glades and Lee, was incorporated into the analyses because of its reliance on Lake Okeechobee for water supply. The LEC area encompasses a sprawling, fast-growing urban complex that, according to the 2000 census, provided homes for 5,089,838 people, primarily along the coast. The planning area has extensive, economically significant agricultural lands and world-renowned environmental resources, including the Everglades ecosystem and Lake Okeechobee, the largest freshwater lake in the southern United States. Highly productive coastal estuaries, such as Biscayne Bay and Florida Bay occur along the shores.

PHYSICAL FEATURES

Climate

The subtropical climate of south Florida, with distinct wet and dry seasons, high rates of evapotranspiration and climatic extremes of floods, droughts and hurricanes, represents a major physical driving force that sustains the Everglades. Seasonal rainfall patterns in south Florida resemble the wet and dry season patterns of the humid tropics more than the winter and summer patterns of temperate latitudes. Wet season rainfall follows a bimodal pattern with peaks during May–June and September–October. The amount of rainfall varies regionally within the District.

Tropical storms and hurricanes also provide major contributions to wet season rainfall with a high level of interannual variability and low level of predictability. During the dry season, rainfall is governed by large-scale winter weather fronts that pass through the region approximately weekly. High evapotranspiration rates in south Florida roughly equal annual precipitation. Recorded annual rainfall in south Florida has varied from 37 to 106 inches, and interannual extremes in rainfall result in frequent years of flood and drought. Multiyear high and low rainfall periods often alternate on a timescale approximately of decades.

South Florida's climate, in combination with low topographic relief, delayed the development of south Florida until the twentieth century. The storm of 1947 caused extensive flooding in south Florida and prompted the U.S. Congress to authorize the U.S. Army Corps of Engineers (USACE) to design and construct the Central and Southern Florida Flood Control Project (C&SF Project). Water supply and flood control issues in the agricultural and urban segments continue to drive the water management planning of the Comprehensive Everglades Restoration Plan (CERP) and the *Lower East Coast Regional Water Supply Plan* (LEC Plan) today.

Physiography

The surface features of central and southern Florida are largely of marine or coastal origin with subsequent erosion and modification by non-marine waters. The features include flat, gently sloping plains, shallow water-filled depressions, elevated sand ridges and a limestone archipelago. The elevations of the ridges and plains are related to former higher stands of sea level. Some ridges have been formed above the level of these higher seas as beach ridges, while the plains developed as submarine shallow sea bottoms.

The topography of the District has low elevation and wide areas of very low relief. Nearly the entire District is less than 200 feet above sea level and nearly half its area is less than 25 feet above sea level. Elevations within the District generally decline from north to south.

The bottom of Lake Okeechobee is approximately at sea level. Water levels in the lake generally range from 11 to 18 feet NGVD. The land immediately surrounding Lake Okeechobee is at an elevation of about 20 to 25 feet NGVD. The coastal regions and most of the peninsula south of the latitude of Lake Okeechobee lie below 25 feet NGVD in elevation. From Lake Okeechobee southward, an axial basin, occupied by the lake and the Everglades, occurs near the longitudinal center of the peninsula with slightly higher ground to the east and west. A small area near Immokalee and parts of the Atlantic Coastal Ridge are higher than 25 feet NGVD. Except for the coastal and beach ridges, this southern region is very flat in appearance and slopes vary gradually from approximately 25 feet NGVD near Lake Okeechobee to sea level at the coasts.

Land elevations in the Water Conservation Areas (WCAs) generally range from about 16 feet NGVD at the northern end of WCA-1 to about 9 to 10 feet NGVD at the southern end of WCA-3. Within Everglades National Park, the land surface generally slopes from 8 to 9 feet NGVD at the northern end to below sea level as the freshwater wetlands of the Everglades merge with the saltwater wetlands of Florida Bay.

WATER RESOURCES AND SYSTEM OVERVIEW

Regional Hydrologic Cycle

The main components of the hydrologic cycle are precipitation (and the resulting infiltration); evapotranspiration (and the resulting withdrawal); surface water inflow and outflow; and groundwater flow.

Precipitation and Evapotranspiration

The average annual precipitation in the LEC Planning Area is approximately 53 inches. Nearly 75 percent of the rainfall occurs during the six-month wet season from May through October. Much of this rainfall is returned to the atmosphere by plant transpiration or evaporation from soils and water surfaces. Hydrologic and meteorologic methods are available to measure and/or estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as evapotranspiration (ET). Evapotranspiration in south Florida returns approximately 45 inches of water per year to the atmosphere.

Surface Water Resources

The LEC Planning Area is divided into three hydrologically related geographical areas consisting of: 1) Lake Okeechobee and the Lake Okeechobee Service Area, which includes the Everglades Agricultural Area; 2) the Everglades Protection Area, which includes the Holey Land and Rotenberger Wildlife Management Areas, the five Water Conservation Areas and Everglades National Park; and 3) the Lower East Coast canals and the Lower East Coast Service Areas (**Figure 14**). **Figure 14** also shows the St. Lucie Canal (C-44) and the Caloosahatchee River basins (C-43) as areas located outside the LEC Planning Area with significant relationships to the LEC planning process. These two basins were included within the LEC planning process because of their dependence on Lake Okeechobee for water supply and concerns about environmental impacts associated with regulatory releases from Lake Okeechobee.

Lake Okeechobee

The major features of Lake Okeechobee and the Lake Okeechobee Service Area (LOSA) are shown in (**Figure 14**). Lake Okeechobee, Florida's largest lake (730 square miles) has a water storage capacity of over 1 trillion gallons of water and represents the heart of the C&SF Project. The lake is managed jointly by the SFWMD and USACE as a multipurpose reservoir. Its multiple functions include flood control, agricultural and urban water supply, navigation, recreation, fish and wildlife enhancement. Major inflows to the lake include the Kissimmee River, Fisheating Creek and Taylor Creek/Nubbin Slough. The lake supports an extensive littoral zone (154 square miles) that provides

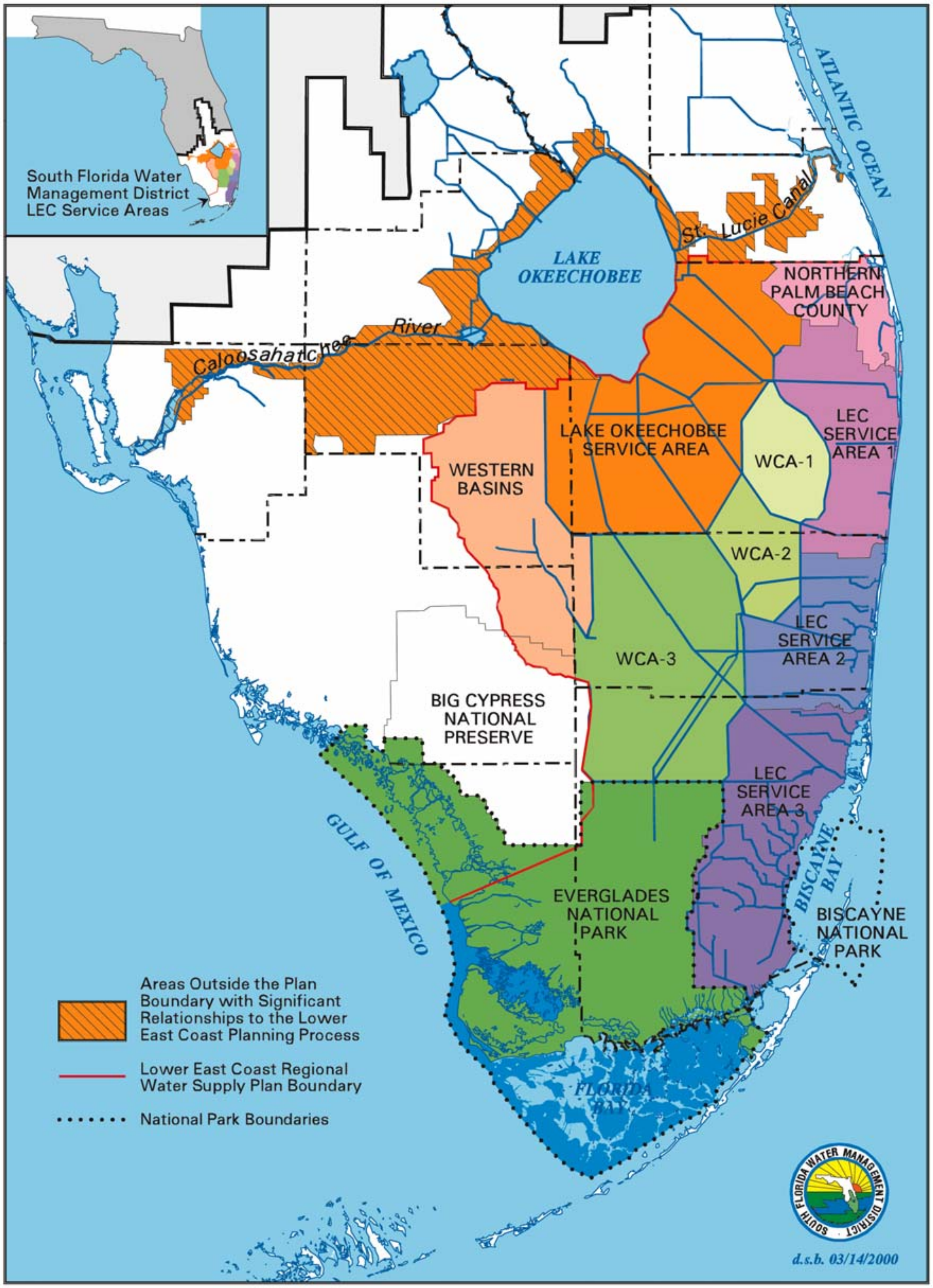


Figure 14. Major Features of the Lower East Coast Planning Area.

important feeding and nesting habitat for fish, wading birds, migratory waterfowl, as well as the endangered Everglades snail kite. The lake is nationally renowned for its fishing (black bass and crappie) and supports a viable commercial and sportfishing industry. Migratory birds and waterfowl also use the littoral zone and open water areas of the lake as a resting area along the Atlantic flyway. Recreational and commercial fisheries are valued in multimillions of dollars per year. The lake's littoral zone also supports significant wading bird populations and is an important waterfowl hunting area.

Water levels in Lake Okeechobee are regulated by a complex system of pumps and locks. A regulation schedule has been established for Lake Okeechobee to achieve multiple uses and provide seasonal lake level fluctuations that vary from high stages in the late fall, winter and early spring to low stages at the beginning of the wet season. More details concerning the operation of Lake Okeechobee can be found under the Water Supply section of this chapter.

Everglades Agricultural Area

The Everglades Agricultural Area (EAA) is located within the Lake Okeechobee Service Area (**Figure 14**), south of Lake Okeechobee within eastern Hendry and western Palm Beach counties. The EAA encompasses 718,400 acres (1,122 square miles) of highly productive agricultural land comprised of rich organic peat or muck soils. Approximately 77 percent of the EAA (553,000 acres) is in agricultural production. Nitrogen-rich organic (peat) soils and a warm subtropical climate permit the year-round farming of sugarcane, winter vegetables and rice.

Agriculture within the EAA requires extensive drainage of 553,000 acres of rich organic soil. The primary drainage and irrigation system within the EAA consists of an extensive network of canals, levees, pumps and water control structures constructed by the USACE as part of the C&SF Project, and operated and maintained by the District. Drainage of the EAA is achieved through six primary canals (Hillsboro, North New River, Miami, West Palm Beach, Cross and Bolles canals). Seven major pump stations have a total design capacity to remove excess water from each subbasin at a maximum rate of ¾ of an inch of runoff per day. Nine smaller, drainage districts known as the Chapter 298 Special Drainage Districts, also maintain secondary drainage systems and operate pump facilities within the EAA to provide local control of water movement within and between subbasins. In addition, individual farms operate numerous private pumps, some of which are portable, that move water to and from the main canals.

Everglades Protection Area

The Everglades Protection Area lies south of the EAA, west of the Atlantic Coastal Ridge, and east of the Big Cypress Preserve. It is comprised of a number of different management areas that have different operational needs and priorities, including the five Water Conservation Areas (WCAs); the Holey Land and Rotenberger Wildlife

Management Areas (WMAs); and Everglades National Park, which includes Florida Bay (**Figure 14**).

The Everglades is an internationally recognized ecosystem that covers approximately two million acres in south Florida and represents the largest subtropical wetland in the United States. Prior to drainage and development, this area consisted largely of vast sawgrass plains, dotted with tree islands and interspersed with wet prairies and aquatic sloughs covering most of southeastern Florida (Davis, 1943). Everglades National Park and the WCAs are the surviving remnants of the historical Everglades, which extended over an area approximately 40 miles wide by 100 miles long, from the south shore of Lake Okeechobee to the mangrove estuaries of Florida Bay. This remaining area provides significant ecological, water storage, flood control and recreational benefits to the region, as well as important habitat for wildlife of national significance. The predrainage Everglades had three essential characteristics: 1) it was largely a rain-driven ecosystem; 2) it contained large spatial scale and extent; and 3) its hydrologic regime featured dynamic storage and sheet flow.

Water Conservation Areas

Construction of canals, levees and water control structures as part of the C&SF Project has compartmentalized the historical Everglades into five separate reservoirs (**Figure 14**) known today as the Water Conservation Areas (WCAs). The five WCAs contain the last remnants of the tall sawgrass, wet prairie, deep-water slough and tree island landscapes that remain intact outside of Everglades National Park. The WCAs are completely contained by levees, except for about 7 miles on the west side of WCA-3A, which has a tieback levee. Additional levees on the east side of the Everglades protect adjacent agricultural, urban and industrial areas. This whole region is managed with a system of canals, pump stations and control structures.

The WCAs provide a detention reservoir for excess water from the EAA and parts of the LEC Planning Area, and for flood discharges from Lake Okeechobee. The WCA levees prevent the Everglades floodwaters from inundating east coast urban areas and hold backwater that can later be supplied to east coast areas and Everglades National Park. In addition, these levees help maintain higher water levels that provide recharge to the Surficial Aquifer System, ameliorate saltwater intrusion in coastal basins, reduce seepage and benefit fish and wildlife in the Everglades.

The WCA regulation schedules essentially represent seasonal and monthly limits of storage. This seasonal range permits the storage of runoff during the wet season for use during the dry season. In addition, it maintains and preserves native plant communities, which are essential to fish, wildlife and the prevention of wind tides. Additional descriptions of WCAs 1, 2 and 3 and their respective regulation schedules are provided under the Water Supply section of this chapter.

Everglades National Park

South of the WCAs lies Everglades National Park, encompassing 2,353 square miles of wetlands, uplands and submerged lands located within the southern portion of the LEC Planning Area (**Figure 14**). The park contains both temperate and tropical plant communities, including sawgrass prairies, mangrove and cypress swamps, pinelands and hardwood hammocks, as well as marine and estuarine environments. The topography of this area is extremely low and flat, with most of the area lying below 4 feet NGVD. The southern portion of the park includes saline wetlands, including mangrove and buttonwood forests, salt marshes and coastal prairie that are subject to the influence of salinity from tidal action. The park has been recognized for its natural and cultural resources, as well as for its recreational values and has been designated an International Biosphere Reserve, a World Heritage Site and a Wetland of International Importance. Everglades National Park is known for its abundant bird life, particularly large wading bird colonies including the roseate spoonbill, wood stork, great blue heron and a variety of egrets. Its abundant wildlife includes rare and endangered species, such as the American crocodile, Florida panther and West Indian manatee. Sheet flow from the park flows southward and enters Florida Bay principally through 20 creek systems fed by Taylor Slough and the C-111 Canal. Surface water from Shark River Slough flows to the southwest into Whitewater Bay.

East Coast Canals and Service Areas

Coastal Canals

Flood control and outlet works extend from St. Lucie County southward through Martin, Palm Beach and Broward counties to Miami-Dade County, a distance along the coast of about 170 miles. The South Miami-Dade Conveyance System was added to the existing flood control system to provide a way to deliver water to areas of south Miami-Dade County. The main design functions of these project canals and structures are to 1) protect adjacent lands against floods; 2) store water in the WCAs; 3) control water elevations; and 4) provide water for conservation and human uses. These works protect against major flood damages. However, due to urbanization, the existing surface water management system now has to handle greater peak flows than in the past. Project works consist of 40 operating canals, 50 operating structures and one levee. The operating structures consist of 35 spillways, 14 culverts and one pump station. Many of these canals are used to remove water from interior areas to tidewater. Damages to agriculture, citrus and pasturelands have been reduced due to the effective drainage capabilities of the canals. The project works maintain optimum stages for flood control, water supply, groundwater recharge and prevention of saltwater intrusion.

Areas become flooded during heavy rainfall events due to antecedent conditions that cause saturation and high runoff from both developed and undeveloped areas. To reduce the threat of flooding, automatic controls have been installed on some control structures. Saltwater intrusion has declined considerably at coastal structures since the installation of salinity dams downstream and salinity sensors near the structures.

The coastal canals and control structures are designed to permit rapid removal of floodwaters from their immediately adjacent drainage area. The degree of flood protection provided by outlet capacity depends on whether the protected area is urban or agricultural. Maximum rates of removal vary from 40 to 100 percent of the Standard Project Flood (SPF).

The network of canals and control structures also provide capacity for water supply and salinity control in the area. Releasing water from the WCAs and conveying this water through coastal canals to the vicinity of the wellfields significantly recharge the wellfields, which are the primary source of municipal water supplies. Water stored in the WCAs can also be used to maintain groundwater levels, a freshwater head for salinity control in the coastal area and to irrigate agricultural areas.

North Palm Beach Service Area

The North Palm Beach Service Area (NPBSA) includes all of the coastal and inland portions of northern Palm Beach County west of the EAA and north of the West Palm Beach Canal Basin (**Figure 14**). In presenting the results of the plan, the southern L-8 Basin and the M-Canal/Water Catchment Area basins are included within the NPBSA. This service area contains extensive urban, agricultural and natural areas. The major natural areas within the NPBSA include the DuPuis Reserve, the J.W. Corbett Wildlife Management Area, the West Palm Beach Water Catchment Area, the Loxahatchee Slough, the Loxahatchee River and the Pal Mar Wetlands. The urban areas have experienced rapid growth for several decades and a continuation of this growth is expected to continue through 2010. Agricultural land uses occur mostly in the L-8 and C-18 basins. The major utilities in the NPBSA include West Palm Beach, Riviera Beach, Seacoast, Jupiter and Tequesta.

Lower East Coast Service Area 1

The Lower East Coast Service Area 1 (LECSA-1) includes the portion of Palm Beach County east of WCA-1 and a small portion of Broward County (**Figure 14**). The service area includes the West Palm Beach Canal (C-51) and Hillsboro basins. This service area is heavily urbanized and has experienced rapid growth for several decades. A large amount of agriculture, principally winter vegetables, citrus and nurseries are located in the western portions of the service area. Utilities within Palm Beach County, which are in LECSA-1 include Lake Worth, Lantana, Delray Beach, Highland Beach, Boca Raton, Royal Palm Beach, Acme, Palm Beach County, Palm Springs, Atlantis, Jamaica Bay, Boynton Beach, Manalapan and the Village of Golf. The utilities in Broward County, within the LECSA-1 include a section of Broward County 2A, Deerfield Beach, the North Springs Improvement District and Parkland.

Lower East Coast Service Area 2

Lower East Coast Service Area 2 (LECSA-2) includes the portion of Broward County east of the WCAs and south of the Hillsboro Canal Basin and the C-9 Canal Basin in northern Miami (**Figure 14**). This LECSA-2 is heavily urbanized and has experienced rapid growth for several decades. While the rate of growth is slowing, the increasing population results in significant increases in demand for potable water.

Utilities within Broward County that are within LECSA-2 include Broadview, Broadview Park, Broward County 1A, 1B, 3A and 3B; Cooper City, the City of Coral Springs, Coral Springs Improvement District, Dania, Davie, Ferncrest, Fort Lauderdale, Hallandale, Hillsboro Beach, Hollywood, Lauderhill, Margate, Miramar, North Lauderdale, Pembroke Pines, Plantation, Pompano Beach, Royal, Seminole Industries, South Broward, Sunrise and Tamarac. One utility within Miami-Dade County, North Miami Beach, also lies within this area.

Lower East Coast Service Area 3

Lower East Coast Service Area 3 (LECSA-3) includes that portion of Miami-Dade County east of WCA-3B and Everglades National Park, as well as the Florida Keys (**Figure 14**). The Florida Keys are included in LECSA-3 because their primary source of drinking water is the Florida Keys Aqueduct Authority Wellfield located near Florida City.

Other major water suppliers in this service area include Miami-Dade Water and Sewer Department, the city of North Miami, the city of Homestead, Florida City and Homestead Air Force Base.

Water demand in LECSA-3 is generated primarily by a mixture of urban and agricultural land uses. Population is expected to grow and displace some of the agriculture in southern Miami-Dade County. The citrus, winter vegetables and tropical fruit farming in southern Miami-Dade County represent the second largest agricultural area in south Florida. Early efforts to drain the area caused significant saltwater intrusion and the abandonment of coastal wellfields in favor of large, regional wellfields located west of the Atlantic Coastal Ridge. The saltwater intrusion situation along the coast appears to have stabilized.

During dry periods, rainfall and seepage are insufficient to maintain the Biscayne Aquifer at levels that meet demands and prevent saltwater intrusion. In these times, the area is highly dependent on additional deliveries from regional storage via the C-4 and C-6 canals for the recharge of major public water supply wellfields.

Besides local rainfall, LECSA-3 receives large quantities of regional water due to groundwater seeping from WCA-3B and Everglades National Park. Due to this seepage, efforts to restore water levels in areas west of the levee system to historic levels affect the drainage needs of land uses east of the levee system, while helping to recharge major public water supply wellfields.

Water Quality Issues

Lake Okeechobee is at the center of the south Florida ecosystem/watershed, receiving flow from the Kissimmee River Basin and, to a lesser extent, from Everglades Agricultural Area (EAA) backpumping. The lake may be considered a historically eutrophic water body that is becoming degraded, due primarily to the interruption of natural sheet flow and nutrient inputs from the tributaries and surrounding land uses. Despite extensive pollutant abatement programs, recent lake data indicate that nutrient concentrations and loads have shown no substantive improvement. Because so much phosphorus is being stored within the lake's sediment, acting as a phosphorus reservoir and continuing to release phosphorous to the water column of the lake, phosphorus levels in lake waters may not reach acceptable levels for many decades.

Water quality in the Caloosahatchee River is degraded in the upper and lower areas of the basin, due to agricultural and urban runoff, respectively. Problems associated with the degraded areas are typified by low dissolved oxygen levels, elevated conductivity and decreased biodiversity. In urban sections of the basin, nonpoint stormwater flows are associated with periodic algal blooms, fish kills and low dissolved oxygen levels.

Extensive agricultural Best Management Practices (BMPs) have been applied in the EAA in the past several years to reduce the phosphorus load leaving the EAA. However, this area remains a primary source of pollutants for the WCAs. Drainage of muck soils for crop production causes soil oxidation and the release of nutrients into EAA runoff waters. During the wet season, growers commonly pump large volumes of nutrient enriched water off their land to protect crops from flooding. These waters also are contaminated with chlorides, dissolved minerals, iron (derived from EAA groundwater), nutrients and trace levels of pesticides. The highly altered hydroperiod, resulting from the levees and pump operations, may exacerbate water quality conditions in the WCAs, as evidenced by a general degradation of water quality in the areas along the canals and adjacent to pump stations. The upstream stormwater treatment areas (STAs) are expected to improve water quality conditions in the WCAs through time.

Water bodies in the LEC Planning Area are seriously degraded in the heavily urbanized areas, including the numerous man-made canals. For example, water quality in Lake Worth Lagoon is good near the inlets and poor in the area between the inlets. Canals and water bodies in and around Fort Lauderdale are degraded by urban runoff and historical wastewater discharges, and by agricultural runoff in western portions of the canals. The New River and Miami River canals are polluted by improperly functioning septic tanks, discharges from vessels, industrial activities, improper sewer connections and stormwater runoff. Problems associated with these pollutants vary, but may include high nutrient concentrations, high bacteria counts, dense growth of undesirable aquatic vegetation, low biological diversity, low dissolved oxygen concentrations and the occurrence of exotic plants and animals.

Water quality is good in open water areas of central and southern Biscayne Bay, and degraded in the area north of the Miami River Canal. High concentrations of heavy metals, such as tin, copper, zinc and chromium occur in sediments at marina sites.

Water quality conditions in the Florida Keys are generally good in areas open to the Atlantic or Gulf of Mexico. However, many man-made canals and marinas have water quality problems that are exacerbated by stormwater runoff, seepage from septic tanks and poor circulation.

Groundwater Resources

The principal groundwater resources for the LEC Planning Area are the Surficial Aquifer System (SAS), including the Biscayne Aquifer and the Floridan Aquifer System (FAS). Both are critical to the local ecology and economy. **Figure 15** shows a generalized cross-section of the hydrogeology of south Florida, depicting the aquifers.

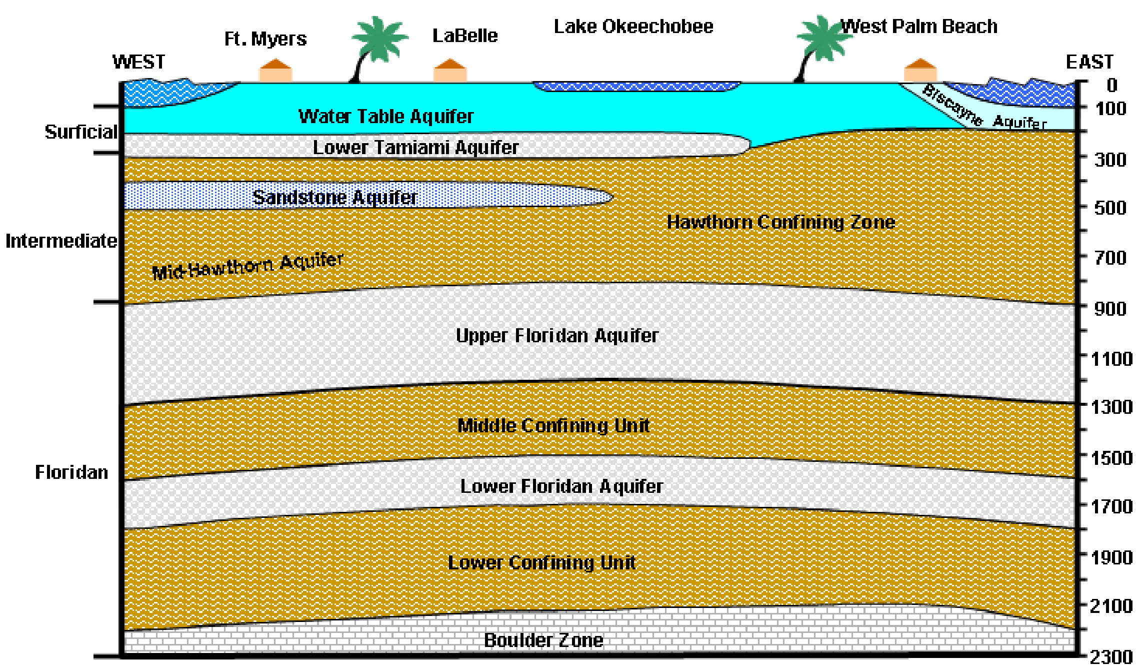


Figure 15. Generalized Geologic Cross-Section of South Florida Showing the Location of the Aquifers.

Surficial Aquifer System

The SAS, which extends throughout southeast Florida, provides most of the fresh water for public and agricultural water supply within the LEC Planning Area. The SAS is an unconfined aquifer system, meaning that the groundwater is at atmospheric pressure and that water levels correspond to the water table. It is composed of solutioned limestone, sandstone, sand shell and clayey sand, and includes sediments from the water table down to the intermediate confining unit (Hawthorn Group). The SAS sediments have a wide range of permeability, and have been locally divided into aquifers separated by less permeable units. The best known of these is the Biscayne Aquifer. One of the most productive aquifers in the world, the Biscayne Aquifer extends from coastal Palm Beach County south, including almost all of Broward and Miami-Dade counties, and portions of southeastern Monroe County. Another less widely utilized aquifer in the SAS is the gray limestone aquifer. The gray limestone aquifer lies below and west of the Biscayne Aquifer, extending into Hendry and Collier counties. The hydrogeology and associated lithology of the SAS is shown in **Figure 16**.

The SAS provides major sources of water for the following uses:

- Meeting drinking water requirements for more than five million people living in urban areas along Florida's Lower East Coast.
- Maintaining water levels in local wells, canals and lakes.
- Irrigating agricultural crops.
- Replenishing regional wetlands and providing base flow to estuaries, such as Biscayne Bay and Florida Bay.

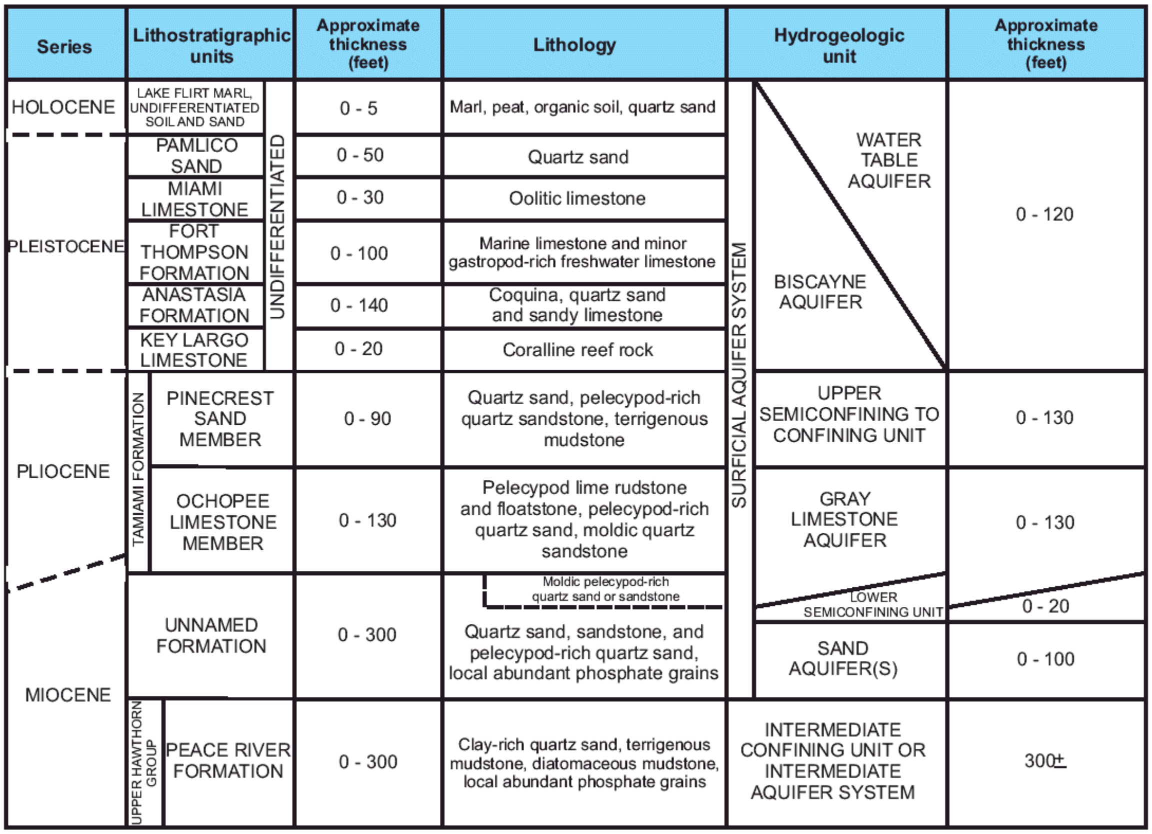


Figure 16. Hydrostratigraphy and Lithology of the Surficial Aquifer System in the Lower East Coast (from Reese and Cunningham, 2000).

Biscayne Aquifer

The Biscayne Aquifer (**Figure 17**) is composed of interbedded, unconsolidated sands and shell units with varying thickness of consolidated, highly solutioned limestones and sandstones. In general, the Biscayne Aquifer contains less sand and more solutioned limestone than most of the SAS. The Biscayne Aquifer is one of the most permeable aquifers in the world and has transmissivities in excess of seven million gallons per day (MGD) per foot of drawdown.

The major geologic deposits that comprise the Biscayne Aquifer include Miami Limestone, the Fort Thompson Formation, the Anastasia Formation and the Key Largo Formation. The base of the Biscayne Aquifer is generally the contact between the Fort Thompson Formation and the underlying Tamiami Formation of Plio-Miocene Age. However, in places where the upper unit of the Tamiami Formation contains highly permeable limestones and sandstones, the zones would also be considered part of the Biscayne Aquifer if the thickness exceeds 10 feet.

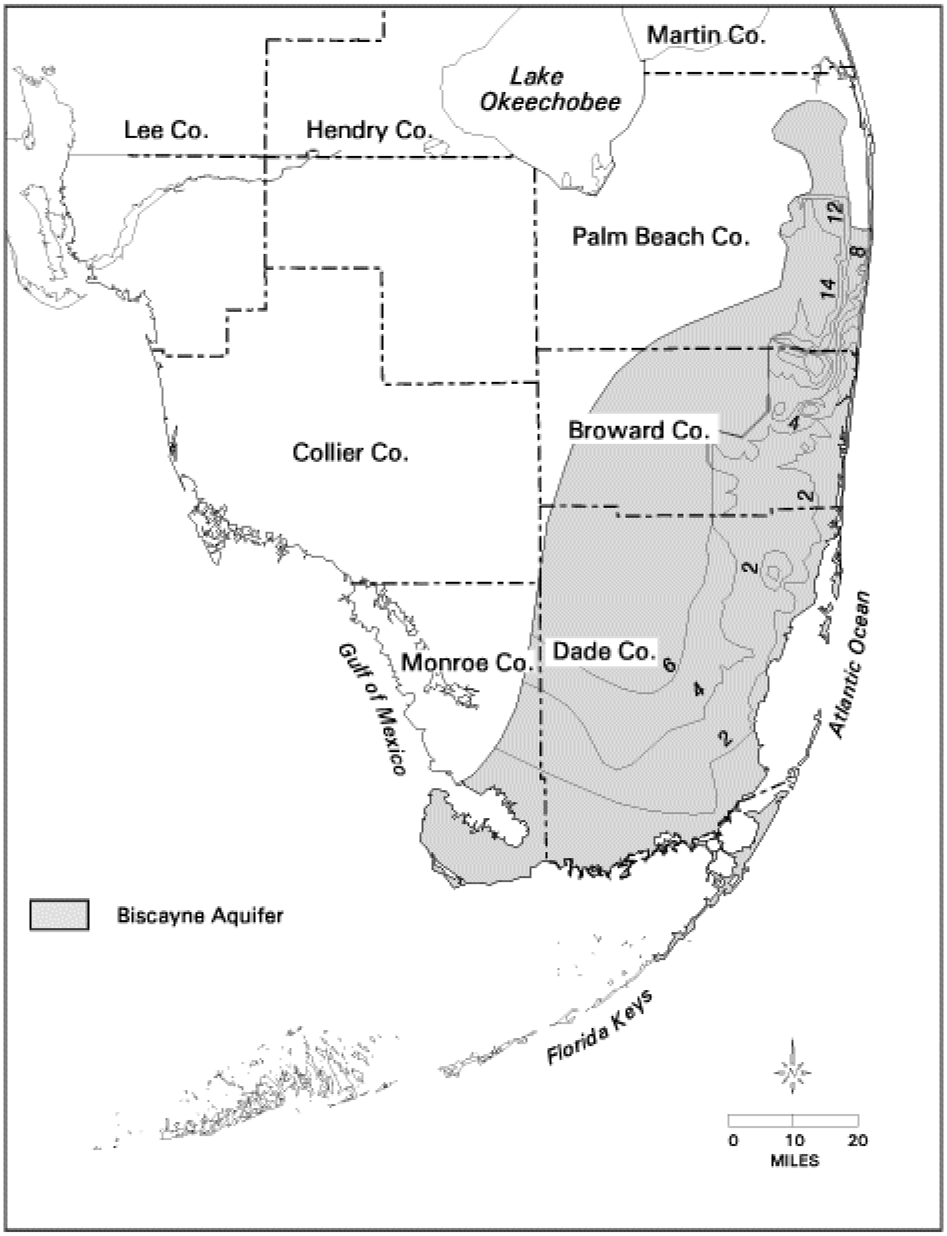


Figure 17. Location of the Biscayne Aquifer in Eastern Miami-Dade, Broward and Palm Beach Counties with Elevation of the Top of the Aquifer. Contour lines are feet NGVD.

Due to the regional importance of the Biscayne Aquifer, it has been designated as a sole source aquifer by the U.S. Environmental Protection Agency (USEPA) under the *Safe Drinking Water Act* and is therefore, afforded stringent protection. This designation was made because it is a principal source of drinking water and is highly susceptible to contamination due to its high permeability and proximity to land surface in many locations. Major sources of contamination are saltwater intrusion and infiltration of contaminants from canal water. Sources of contamination include surface water runoff (pesticides and fertilizers); leachate from landfills, septic tanks and sewage plant treatment ponds; and injection wells used to dispose of stormwater runoff or industrial waste. Trichloroethylene and vinyl chloride are examples of groundwater contaminants of concern. Numerous hazardous waste sites (e.g., *Superfund and Resource Conservation and Recovery Act* sites) have been identified in the area underlain by the Biscayne Aquifer. Action to remove existing contamination is under way at many of these sites. Waste management practices are generally monitored to prevent further contamination.

Gray Limestone Aquifer

The gray limestone aquifer is composed of gray, shelly limestone with abundant shell fragments and sand. The hydraulic conductivity of the gray limestone aquifer generally increases from east to west, and ranges from approximately 200 to 12,000 feet per day. Transmissivity values range from greater than 50,000 feet squared per day west of Miami-Dade and Broward counties to greater than 300,000 feet squared per day in eastern Collier County (Reese and Cunningham, 2000). For most of its extent, the gray limestone aquifer is confined by sand, clayey sand, mudstone, and clays of low hydraulic conductivity (Reese and Cunningham, 2000).

Rapid population growth and development of land in the LEC planning area has created competing demands between municipal users, agricultural lands and sensitive wetland areas. The gray limestone aquifer of the SAS has potential as a supplemental source of water supply for south central Florida.

Floridan Aquifer System

The FAS is a confined aquifer system made up of a thick sequence of limestones, with dolomitic limestone and dolomite commonly found in the lower portions of the aquifer. It is separated from the SAS and confined by the sediments of the Hawthorn Group, which is also referred to as the intermediate confining unit. Less permeable carbonate units, referred to as the middle confining unit, separate the FAS into two major aquifers called the upper and lower Floridan Aquifers (UFA and LFA).

The UFA is comprised of fossiliferous limestones from the Suwannee, Ocala, and Avon Park formations. The potentiometric surface of the UFA ranges from 40 to 60 feet above land surface in the LEC, with groundwater flow occurring primarily within several thin, high-permeability zones. The middle confining unit is relatively less permeable than both the UFA and the LFA. It separates the brackish water of the UFA from the more saline water of the LFA. The LFA is composed of dolostones of the Oldsmar and upper Cedar Keys formations. Groundwater in the LFA is close to seawater in composition, and upwells into the middle confining unit through fractures (Meyer, 1989). **Figure 18** shows the geology and hydrostratigraphy of the FAS in the LEC Planning Area.

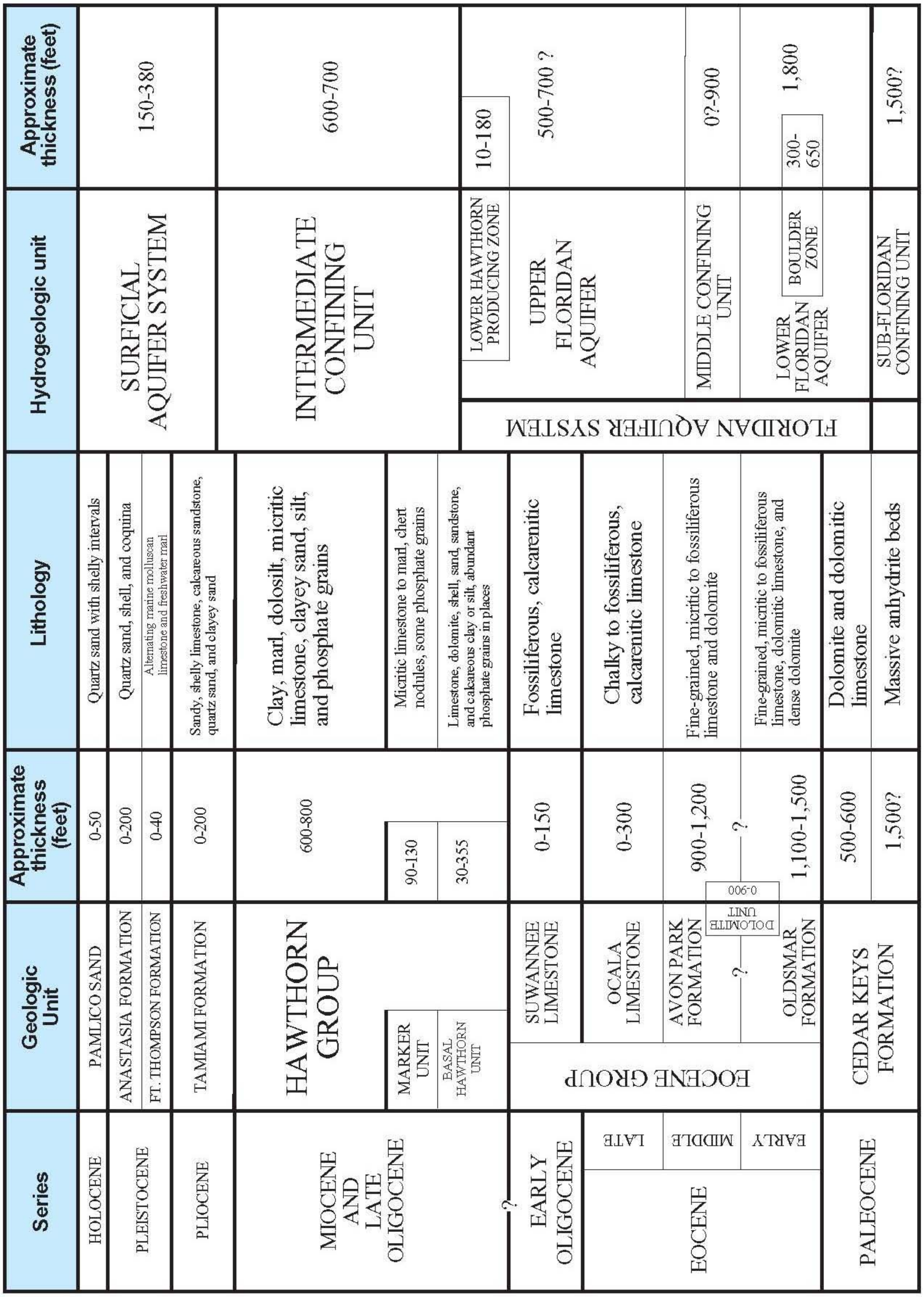


Figure 18. Geology and Hydrostratigraphy of the Floridan Aquifer System in the LEC (from Reese and Memberg, 2000).

The FAS is one of the most productive aquifers in the world and is a multiuse aquifer system. Where it contains fresh water, it is the principal source of water supply, especially north of Lake Okeechobee.

From Jupiter to southern Miami, water from the FAS is highly mineralized and not suitable for drinking water. More than 600 feet of low permeability sediments confine this aquifer and create artesian conditions in the LEC. Although the potentiometric surface of the aquifer is above land surface, the low permeability units of the intermediate confining unit prevent significant upward migration of saline waters into the shallower aquifers. Depth to the Floridan Aquifer is approximately 900 feet in coastal Miami-Dade County. In the LEC Planning Area, the UFA is being considered for storage of potable water within an aquifer storage and recovery (ASR) system. At the base of the LFA), there are cavernous zones with extremely high transmissivities collectively known as the Boulder Zone. Because of their depth and high salinity, these deeper zones of the LFA are used primarily for injection of treated wastewater.

Saltwater Intrusion

The inland movement of salt water is a major resource concern in the coastal areas of the LEC Planning Area and can significantly affect water availability in areas adjacent to saline water bodies. When water is withdrawn from the Surficial Aquifer at a rate that exceeds its recharge capacity, the amount of freshwater head available to impede the migration of salt water is reduced, and saltwater intrusion becomes likely. The groundwater hydrology of the LEC Planning Area has been permanently altered by urban and agricultural development and construction of the C&SF Project. Construction of a series of canals has drained both the upper portion of the Biscayne Aquifer and the freshwater mound behind the coastal ridge. This has resulted in a significant decline in groundwater flow towards the ocean and, consequently, has allowed the inland migration of the saline interface during dry periods. Large coastal wellfields have also been responsible for localized saltwater intrusion problems. Construction of coastal canal water control structures has helped to stabilize or slow the advance of the saline interface, although isolated areas still show evidence of continued inland migration of salt water.

More recently, several wells in the cities of Hollywood, Hallandale and Dania were taken out of service due to saltwater contamination as the recharge capacity of the aquifer was exceeded.

The District's consumptive use permitting (CUP) criteria includes denial of permits that would cause harm to the water resources because of saline water intrusion. Section 3.4, Saline Water Intrusion, of the *District's Basis of Review for Water Use Permit Applications* (SFWMD, 2003a) describes harmful saline water intrusion occurring when:

> Withdrawals result in the further movement of a saline water interface to a greater distance inland toward a freshwater source except as a consequence of seasonal fluctuations; climatic conditions, such as drought; or operation of the Central and Southern Flood Control Project, secondary canal systems, or stormwater systems.

There is potential for withdrawals to permanently move the saline interface inland, reducing the quality and quantity of water available at existing wellfields and impeding future withdrawals at favorable locations (near population centers and treatment plants).

Historically, the District's CUP Program has required water users to maintain a minimum of 1.0 foot of freshwater head between their wellfields and saline water as a guideline for the prevention of saltwater intrusion. This guideline, in combination with a saltwater intrusion-monitoring program, has been largely successful in preventing salt water from occurring based on consideration of individual permits and utility operations. The LEC Plan has taken a more comprehensive view of the potential for saltwater intrusion by identifying areas that are most vulnerable and developing proactive measures to the reduce occurrence of, and better manage, saltwater intrusion.

WATER NEEDS OF INLAND RESOURCES

In the preceding sections, surface water and groundwater resources were addressed as separate entities. However, they are highly interconnected. Local water supply utilities and individual users obtain water from two primary sources: 1) by withdrawal from a surface water body, such as a canal, lake, river or wetland; or 2) by withdrawal from a groundwater well. Virtually all of the LEC public water supply is from groundwater except for the city of West Palm Beach. Throughout much of the LEC Planning Area, a regional system of canals provides a means to move water from one location to another. Water is transported generally from north to south, from Lake Okeechobee through water control structures to the EAA canals and into the WCAs. Water flows from the WCAs via structures and canals to Everglades National Park and the coastal basins. Water in coastal canals provides recharge to the SAS, enhancing groundwater supplies and helping replenish water in lakes, rivers and wetlands.

Lake Okeechobee

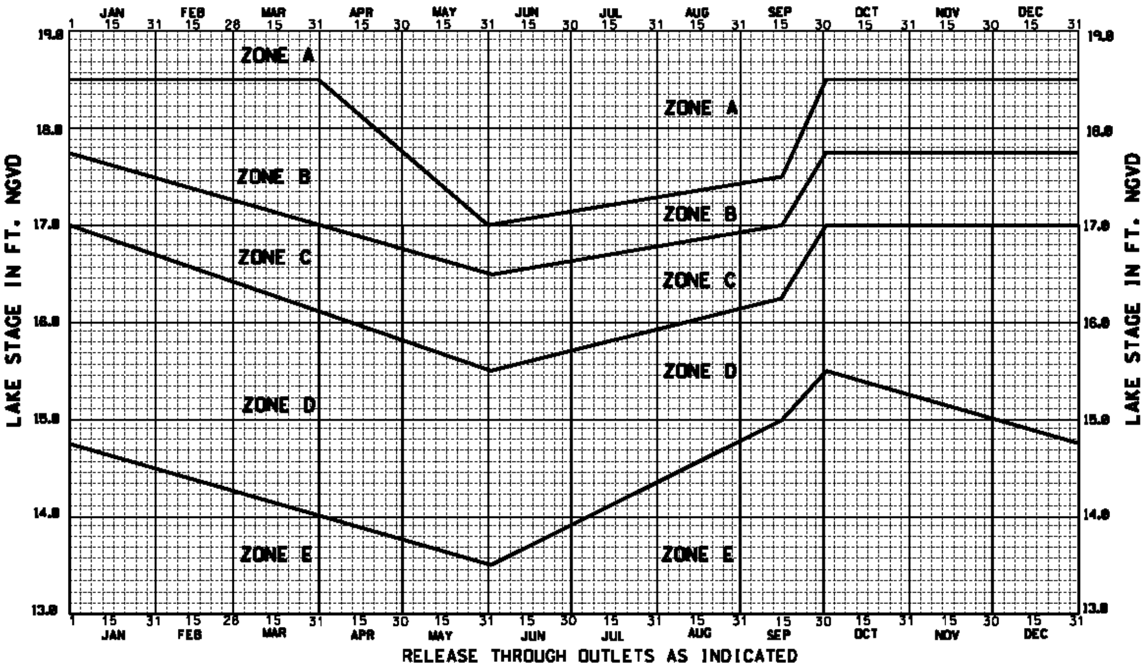
Lake Okeechobee serves a direct source of drinking water for lakeside cities and towns and serves as a backup water supply for urban areas located along the Lower East Coast of Florida. The lake also provides irrigation water for the 700-square-mile EAA located south of the lake and represents a critical supplemental water supply for the Everglades during dry periods. Given these often-competing demands on the lake, management of the water resource is a major challenge. The primary tool for managing lake water levels is the regulation schedule. This schedule defines the ranges of water levels, in which specific discharges are made to control excessive accumulation of water within the lake's levee system. The schedule varies seasonally to best meet the objectives of the C&SF Project. A number of lake regulation schedules have been adopted since the construction of the C&SF Project (Trimble and Marban, 1988).

Lake Okeechobee Regulation Schedule

The Water Supply and Environment (WSE) regulation schedule is the Lake Okeechobee operations schedule in effect since its approval in July 2000. **Figure 19** shows the WSE schedule and its various management zones. Detailed analysis demonstrated that the WSE performance is equal to, or better than the previous regulation schedule, "Run 25," for flood protection, water supply and environmental objectives, including benefits to the lake's ecosystem and downstream estuaries (USACE, 1999).

The WSE schedule is the first schedule to incorporate tributary hydrologic conditions and climate forecasts into its operational guidelines and is used in conjunction with the WSE Operational Guidelines Decision Tree for operation of the lake (USACE, 2000). The Decision Tree is used to help water managers make decisions on whether or not lake regulatory releases should be made to downstream water bodies, such as the Water Conservation Areas or to tidewater via the St. Lucie Canal (C-44) or Caloosahatchee River (C-43). The range of water released to the estuaries in the Decision Tree ranges from "up to maximum discharge" in the case where the lake is in Zone A of the regulation schedule, and "no discharge to tide" when the lake is in Zone D and tributary conditions are dry. A key feature of the WSE schedule is the lower operational zone, Zone D, which allows the flexibility to deliver water to the Everglades WCAs during lower lake stages. The WSE schedule also allows dry season discharges to the estuaries to be gradually increased as necessary to control water levels, and allows more water to be kept in the regional system for water supply and hydroperiod restoration (USACE, 1999).

The WSE schedule also allows for adjustments to be made in the timing and magnitude of Lake Okeechobee regulatory discharges based on conditions in Lake Okeechobee's tributary basins and can incorporate extended meteorological and climate outlooks. When regulatory releases are required to be made to each downstream water body, the schedule provides information on possible ranges of discharge volumes, not exact amounts. The SFWMD Governing Board also accepted the Adaptive Protocols for Lake Okeechobee Operations (SFWMD, 2003) as a document to complement the WSE schedule. It describes procedures for making environmental water deliveries from the lake to the Caloosahatchee Estuary under certain conditions. The Adaptive Protocols include quantitative performance measures that scientists use on a weekly basis to evaluate status of the regional system. The SFWMD and USACE continue to look at ways to improve the WSE Schedule within the constraints of its Environmental Impact Statement in order to improve performance of the lake's various purposes.



Releases Through Lake Okeechobee Outlets

Zone	**Agricultural Canals to WCAs** (1, 2)	**Caloosahatchee River at S-7** (1, 2, 4)	**St Lucie Canal at S-80** (1, 2, 4)
A	Pump Maximum Practicable	Up to Maximum Capacity	Up to Maximum Capacity
B (3)	Maximum Practicable Releases	Releases per decision tree (these can range from maximum pulse release up to maximum capacity)	Releases per decision tree (these can range from maximum pulse release up to maximum capacity)
C (3)	Maximum Practicable Releases	Releases per decision tree (these can range from no discharge up to 6500 cfs)	Releases per decision tree (these can range from no discharge up to 3500 cfs)
D (3, 5)	As needed to minimize adverse impacts to littoral zone; no adverse impacts to the Everglades	Releases per decision tree (these can range from no discharge up to 4500 cfs)	Releases per decision tree (these can range from no discharge up to 2500 cfs)
E	No Regulatory Discharge	No Regulatory Discharge	No Regulatory Discharge

Notes: (1) Subject to first removal of runoff from downstream basins.
(2) Guidelines for wet, dry and normal conditions are based on: 1) selected climatic indices and tropical forecasts; and 2) projected inflow conditions. Releases are subject to the guidelines in the WSE Operational Decision Tree, Parts 1 and 2.
(3) Releases through various outlets may be modified to minimize damages or obtain additional benefits. Consultation with Everglades and estuarine biologists is encouraged to minimize effects to downstream ecosystems.
(4) Pulse releases are made to minimize adverse effects to downstream ecosystems.
(5) Only when the WCAs are below their respective schedules.

Figure 19. WSE Schedule for Operation of Lake Okeechobee.

The large-scale discharges sometimes required in the WSE can be damaging to the downstream estuarine systems. Best Management Zones were developed to provide a buffer or safety factor for making early or pulsed releases of lake water to downstream estuaries. These release patterns are called pulse releases because they mimic the pulse release associated with a rainfall event that would normally occur in an upstream watershed of the estuary. This release concept allows the estuary to absorb the freshwater release without drastic or long-term salinity fluctuations. **Table 35** shows specific discharge criteria for the Caloosahatchee River and St. Lucie River estuaries.

Table 35. Pulse Release Schedules for the St. Lucie and Caloosahatchee River Estuaries and their Effect on Lake Okeechobee Water Levels.

Day of Pulse	Daily Discharge Rate (cubic feet per second)					
	St. Lucie S-80 Level I	**St. Lucie S-80 Level II**	**St. Lucie S-80 Level III**	**Caloosa. S-77 Level I**	**Caloosa. S-77 Level II**	**Caloosa. S-77 Level III**
1	1,200	1,500	1,800	1,000	1,500	2,000
2	1,600	2,000	2,400	2,800	4,200	5,500
3	1,400	1,800	2,100	3,300	5,000	6,500
4	1,000	1,200	1,500	2,400	3,800	5,000
5	700	900	1,000	2,000	3,000	4,000
6	600	700	900	1,500	2,200	3,000
7	400	500	600	1,200	1,500	2,000
8	400	500	600	800	800	1,000
9	0	400	400	500	500	500
10	0	0	400	500	500	500
Average Flow	730	950	1,170	1,600	2,300	3,000
Acre-Feet per Pulse and Correlating Lake Level Fluctuations						
Volume (Ac-Ft)	14,480	18,843	23,207	31,736	45,621	59,505
[a]Equivalent Depth (feet)	0.03	0.04	0.05	0.07	0.10	0.13

a. Volume-depth conversion based on average lake surface area of 467,000 acres.

Water Conservation Areas

The three Water Conservation Areas (WCAs) (**Figure 14**) represent a major feature of the LEC Planning Area. The WCAs are located south of Lake Okeechobee and the EAA and comprise an area of about 1,350 square miles. The WCAs provide water storage and detention for excess water discharged from agricultural and urban area, as well as for regulatory releases from Lake Okeechobee. The WCAs provide water supply for LEC agricultural lands and Everglades National Park; provide recharge for the Biscayne Aquifer (the sole source of drinking water to LEC urban areas); and help to retard saltwater intrusion of coastal wellfields. The WCAs contain the region's last remnants of the original sawgrass marsh, wet prairies and hardwood swamps located outside of Everglades National Park. The WCAs are managed as surface water reservoirs using a set of water regulation schedule (**Figures 20, 21** and **22**).

Water Conservation Area 1 (WCA-1) covers an area of 243 square miles and is located in south central Palm Beach County (**Figure 20**). Most of the basin lies within the Arthur R. Marshall National Wildlife Refuge. The area is enclosed by 58 miles of canals and levees and provides storage for excess rainfall, runoff from agricultural lands to the north and west and regulatory releases from Lake Okeechobee. When marsh stages exceed the regulation schedule, water is discharged to south into Water Conservation Area 2A. This area contains a complex mosaic of wet prairies, numerous tree islands and aquatic sloughs and cypress forests that represent the last remaining examples of native (relatively undisturbed) Everglades habitat. The refuge is managed by the U.S. Fish and Wildlife Service under a lease agreement with the SFWMD.

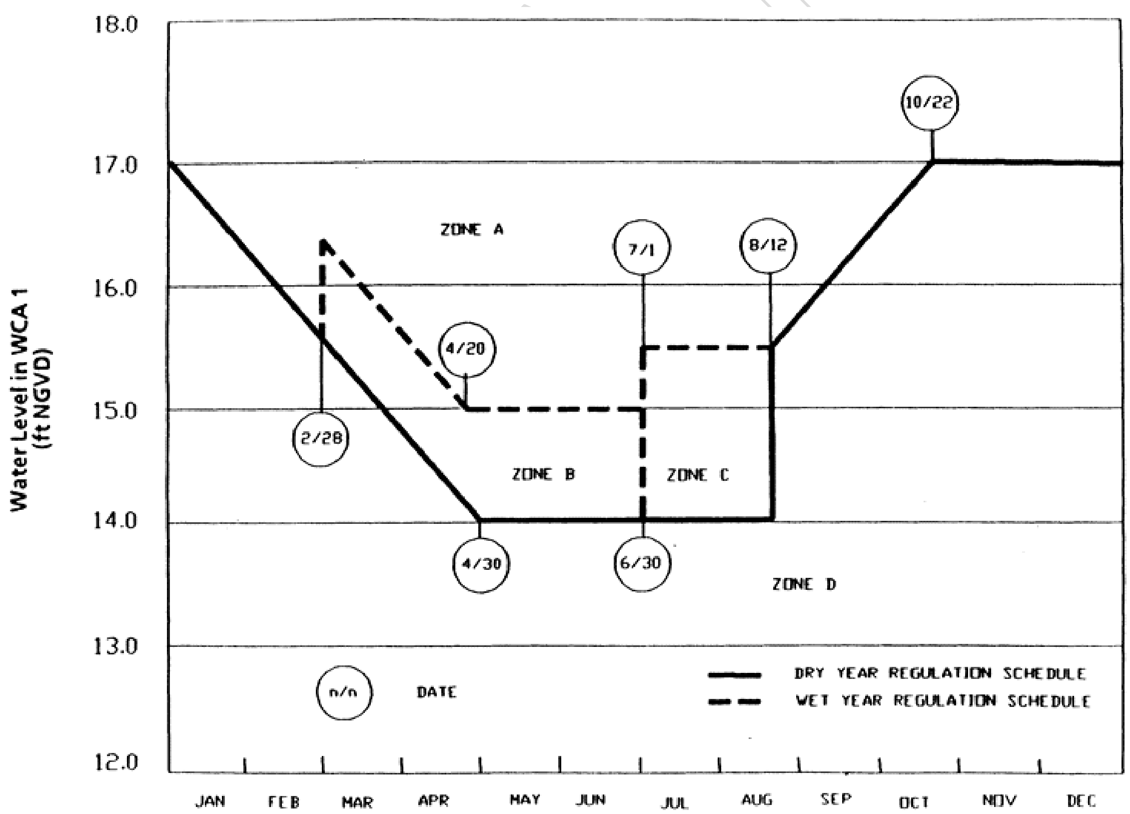


Figure 20. Regulation Schedule for Water Conservation Area 1.

Water Conservation Areas 2A and 2B (**Figure 21**) together comprise about 210 square miles located within southwestern Palm Beach and northwestern Broward counties. WCA-2A provides a 173-square-mile reservoir for storing excess water from WCA-1, as well as agricultural areas located to the west. This area provides wellfield recharge and water supply for urban areas located within Broward County. This area of the Everglades has been the subject of extensive research by the District and other agencies focusing on the problem of vegetation changes (cattails replacing native sawgrass communities) caused by increased nutrient levels and high water levels.

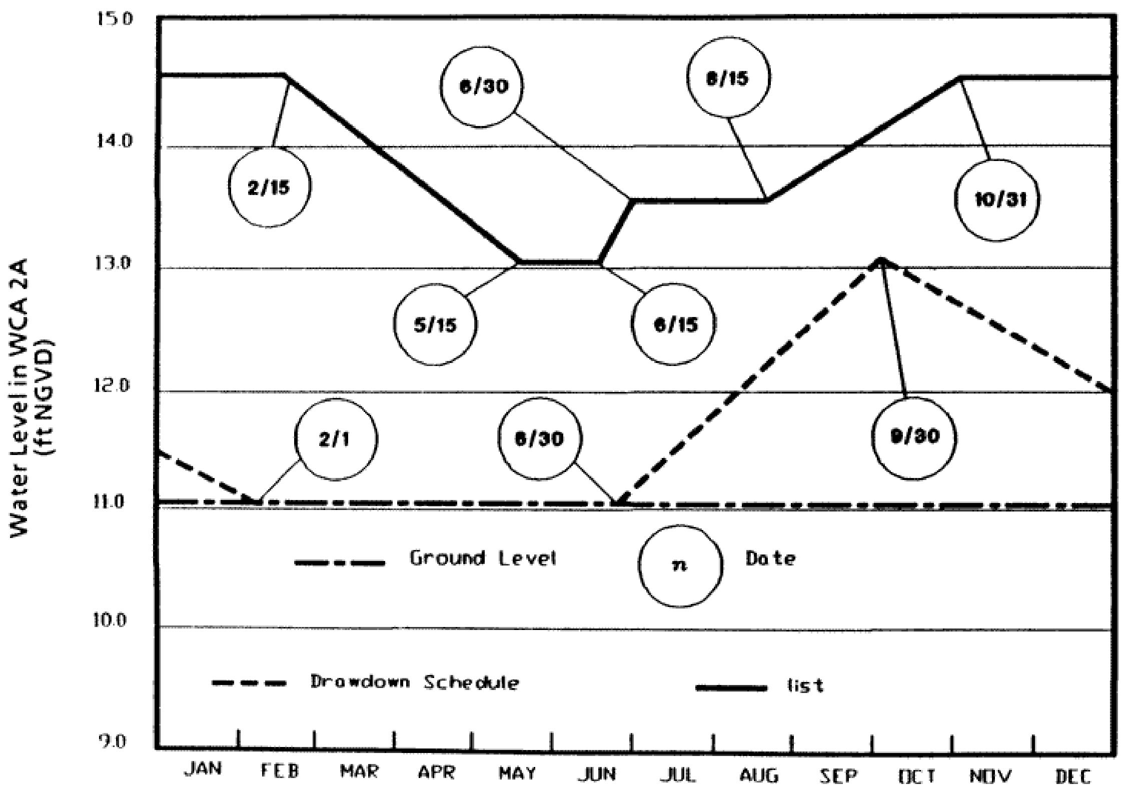


Figure 21. Regulation Schedule for Water Conservation Area 2A.

Water Conservation Area 3A and 3B (**Figure 22**) represent the largest of the three water conservation areas (915 square miles). The Miami Canal traverses WCA-3A from northwest to southeast and receives the majority of its water from direct rainfall, EAA runoff and regulatory releases from Lake Okeechobee. This area also serves as a reservoir to hold excess runoff from WCA-2A, excess rainfall from the Big Cypress Swamp located to the west, as well as flood control discharges from pump station S-9 located within western Broward County. Water stored within WCA-3A and 3B is used to meet the principal water supply needs of adjacent areas, including water supply and salinity control requirements of Miami-Dade and Monroe counties, irrigation requirements for LEC agricultural interests and as a source of water supply fro Everglades National Park. Many areas of WCA-3 still contain vast tracts of habitat consisting of tree islands, sawgrass marshes, wet prairies and aquatic sloughs. However, many areas have been impacted by canal construction and impoundment of the original marsh. These structural changes have caused over drainage of wetlands located within northern WCA-3A and prolonged hydroperiods and deep-water conditions to the south.

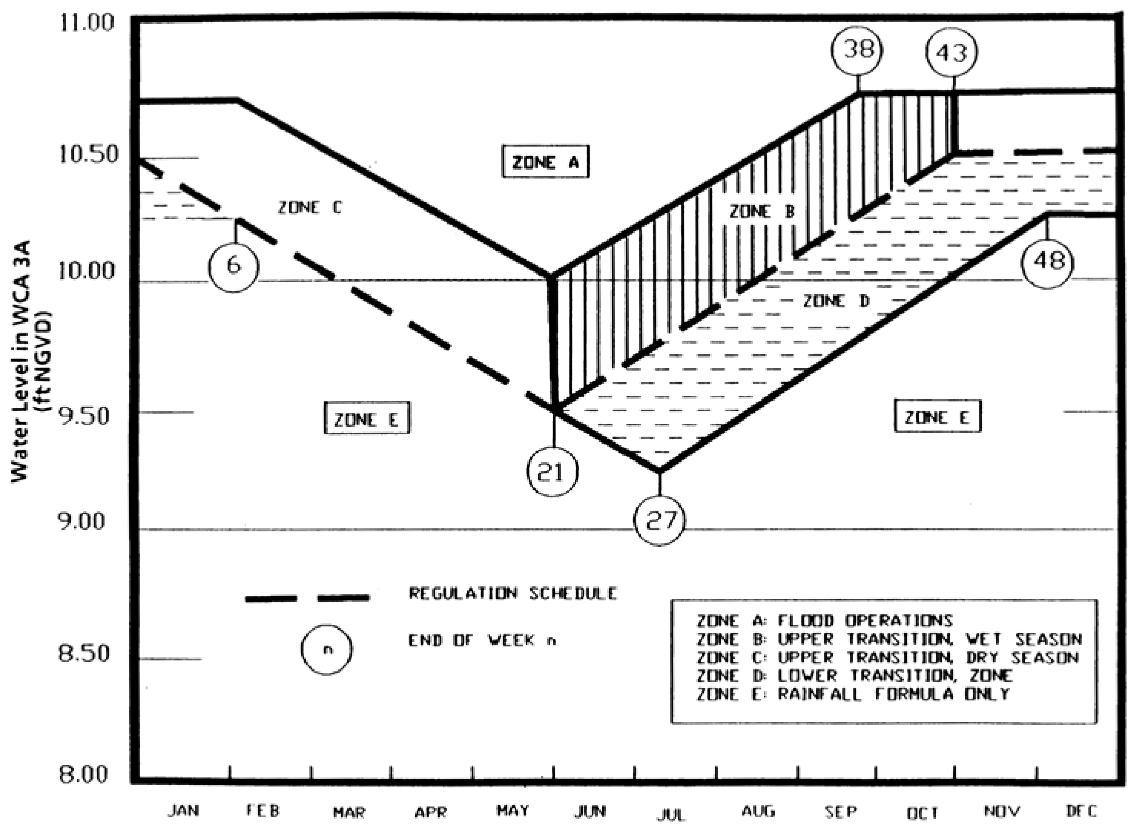


Figure 22. Regulation Schedule for Water Conservation Area 3A.

MANAGEMENT CONSIDERATIONS

One primary function of the C&SF Project is to provide a highly efficient flood control system, which is designed to keep urban and agricultural areas dry in the wet season. Flood protection is provided by discharging excess water to tide or into the WCAs and Everglades National Park. Rapid wet season flood releases to tide, coupled with the reduced capacity to retain water in Lake Okeechobee, the northern historical sawgrass plains and the eastern peripheral wetlands and sloughs, have severely reduced the overall ability to store water in the regional system.

The sawgrass plains, for example, once stored and slowly released much of the water that overflowed from Lake Okeechobee. Today, large areas of these sawgrass plains have been converted to agriculture within the EAA. Water from the lake and excess runoff water are quickly passed to the WCAs and the coast during the wet season to prevent crop damage. Water levels in coastal canals are maintained at relatively low levels during the wet season to provide additional capacity for storage and conveyance of floodwaters, resulting in low groundwater levels.

Another impact of the loss of water storage is that, during the dry season, high levels of demands may exceed the capacity to obtain water from nearby wetlands. When this occurs, water is released from Lake Okeechobee to meet crop and urban demands. Lack of storage, not lack of water, is the problem. During dry periods, minimum levels for LEC canals are principally maintained to protect the Biscayne Aquifer from saltwater intrusion. The head created in the canals raises groundwater levels, recharging the aquifer and the urban wellfields, but also increases the likelihood that localized flooding will occur during an extreme storm event. During the wet season, wellfields are recharged by local rainfall and by seepage from the Everglades and the canals. During the dry season, recharge is more dependent on the regional system. Unfortunately, during both the wet and dry seasons, excess storm water is passed through the canals and out to tide when it should be stored. Without sufficient storage, it is difficult to have water available during dry periods and avoid flooding during wet periods.

While sufficient water is present to meet local needs during wet seasons and normal rainfall years, during extremely dry years, urban wellfields depend heavily on seepage and releases from the WCAs and Lake Okeechobee. During drought years, urban and agricultural areas have additional needs and more water is used for landscape maintenance, primarily lawn irrigation.

The amount of water needed to recharge urban wellfields is less than the volume needed to prevent saltwater intrusion. However, the cost of replacing damaged wells is very high. The amount of water needed to prevent saltwater intrusion, in turn, is much less than the wet season coastal discharges. If coastal flows were captured and stored, more than enough water would be available to maintain dry season salinity barriers without removing water from the natural system.

Within the LEC Planning Area, ecological benefits may accrue from maintaining higher groundwater levels. For example, low groundwater levels have had significant effects on Biscayne Bay, including increased salinity, increased turbidity and lower water quality. In south Miami-Dade County, lowered groundwater levels have caused wetland desiccation and shifts in vegetation from freshwater marshes that existed next to the bay in the early 1900s to salt marsh and mangrove communities that predominate today.

Management During Wet Periods

During wet years, seepage from the Everglades is generally more than adequate to maintain water levels in the coastal aquifers and no releases for this purpose are required. However, releases through coastal canals may be required to maintain regulation schedules in natural storage areas, such as Lake Okeechobee and the WCAs and to provide flood protection.

In order to promote development of coastal basins for urban and agricultural use during the past century, water levels along the coastal ridge have been lowered by construction of drainage facilities. Over time, drainage has continued further westward to allow replacement of most of the wetlands in the Transverse Glades areas in Miami-Dade and Broward counties with homes, farms and nurseries. Large areas have been mined for the underlying rock, which is used for roads and fill.

Due to the high transmissivity of the surficial Biscayne Aquifer, lowering of water levels to protect one area results in reduction of water levels over large areas. Attempts to provide drainage and flood protection to coastal areas have lowered water tables and shortened hydroperiods of wetlands further west into the Everglades. Large amounts of fresh water that would have remained in these wetlands or moved slowly southward to Everglades National Park have been lost as surface water flow through coastal canals to Biscayne Bay.

Analyses conducted for the Restudy and for the development of the LEC Plan have attempted to compensate for the effects of drainage by establishing long-term restoration goals and management targets that reflect how the natural systems functioned before the area was drained. The Natural System Model (NSM) is used to represent predrainage conditions by simulating hydrologic conditions that existed before canals were constructed and before water levels and topography were altered by drainage. The water levels predicted by the NSM, in conjunction with historical data and expert opinion, were used during the Restudy as a basis to establish restoration goals for both low water and high water conditions. Consumptive use permits, in turn, consider these restoration water levels as the no harm standard that should be maintained under all conditions less severe than a 1-in-10 year drought.

Due to the conceptual nature of the Restudy and the modeling tools used for the alternative analyses, detailed flood damage assessment was not performed for the Restudy. However, maintaining levels of flood protection remains an important purpose of the C&SF Project and an objective of the CERP. The U.S. Army Corps of Engineers (USACE) will carefully evaluate any potential flood control impacts before any CERP components are built. Project Implementation Reports (PIRs) for individual components, or groups of components, will include a detailed review of flood protection for the area affected by the components. Opportunities for enhancing flood protection in conjunction with other design objectives will be investigated. In addition, the Restudy report includes the provision that, "Flood level protection monitoring will ensure that the existing level of protection is not compromised as a result of implementation of the recommended plan." (USACE and SFWMD, 1999)

Management During Droughts

During dry years, additional water may be released from the regional system through the coastal canals to help recharge the Surficial Aquifer System in the coastal basins. Triggered either by a decline in water levels in the canals below their maintenance levels or a movement of the saltwater front in the coastal aquifers, these water supply releases are made on an as needed basis. **Figures 23** and **24** show how regional water conveyance facilities are managed during wet and dry periods.

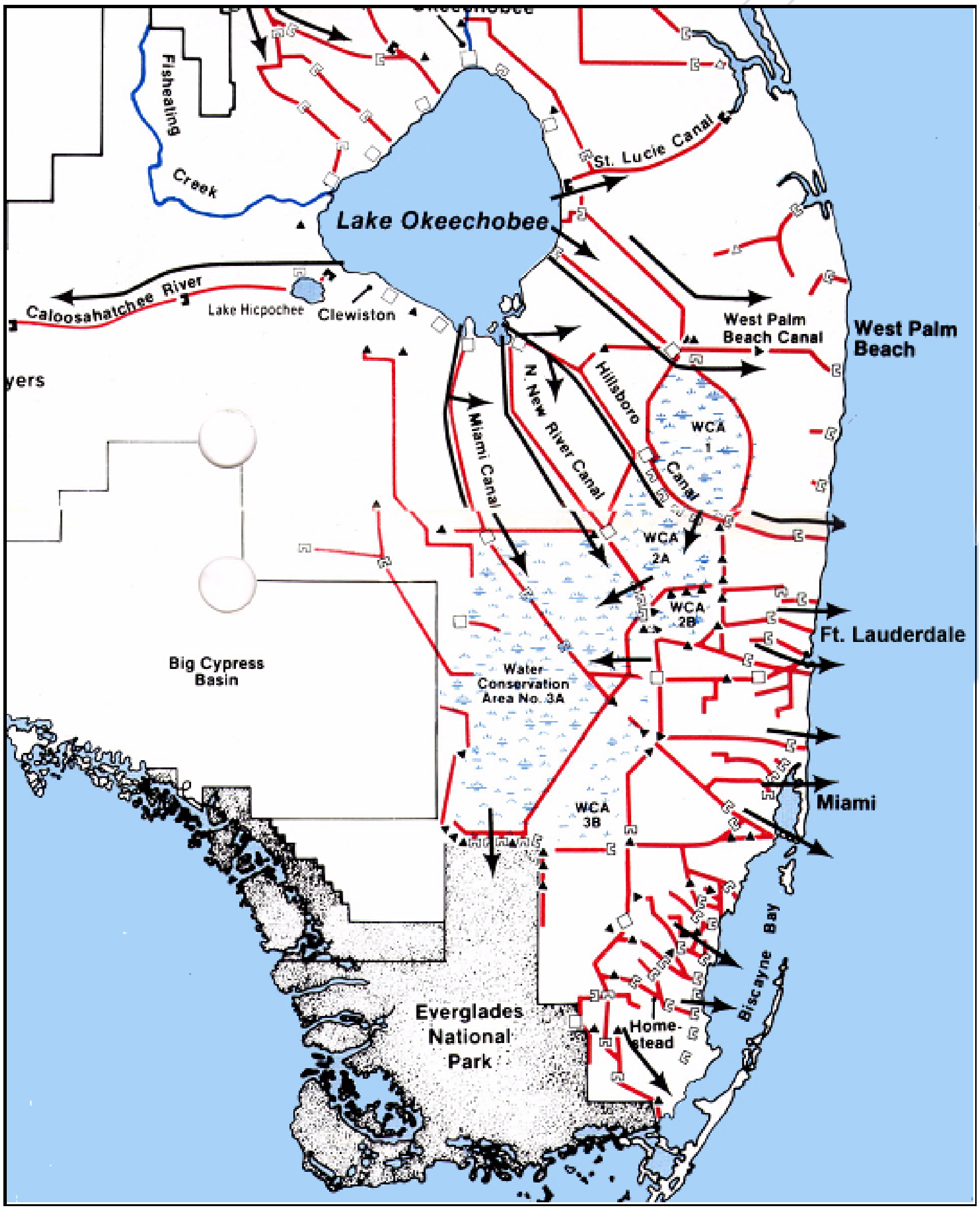


Figure 23. Water Conveyance in the Regional Systems During Wet Period. Arrows Indicate Direction of Pumpage or Flow.

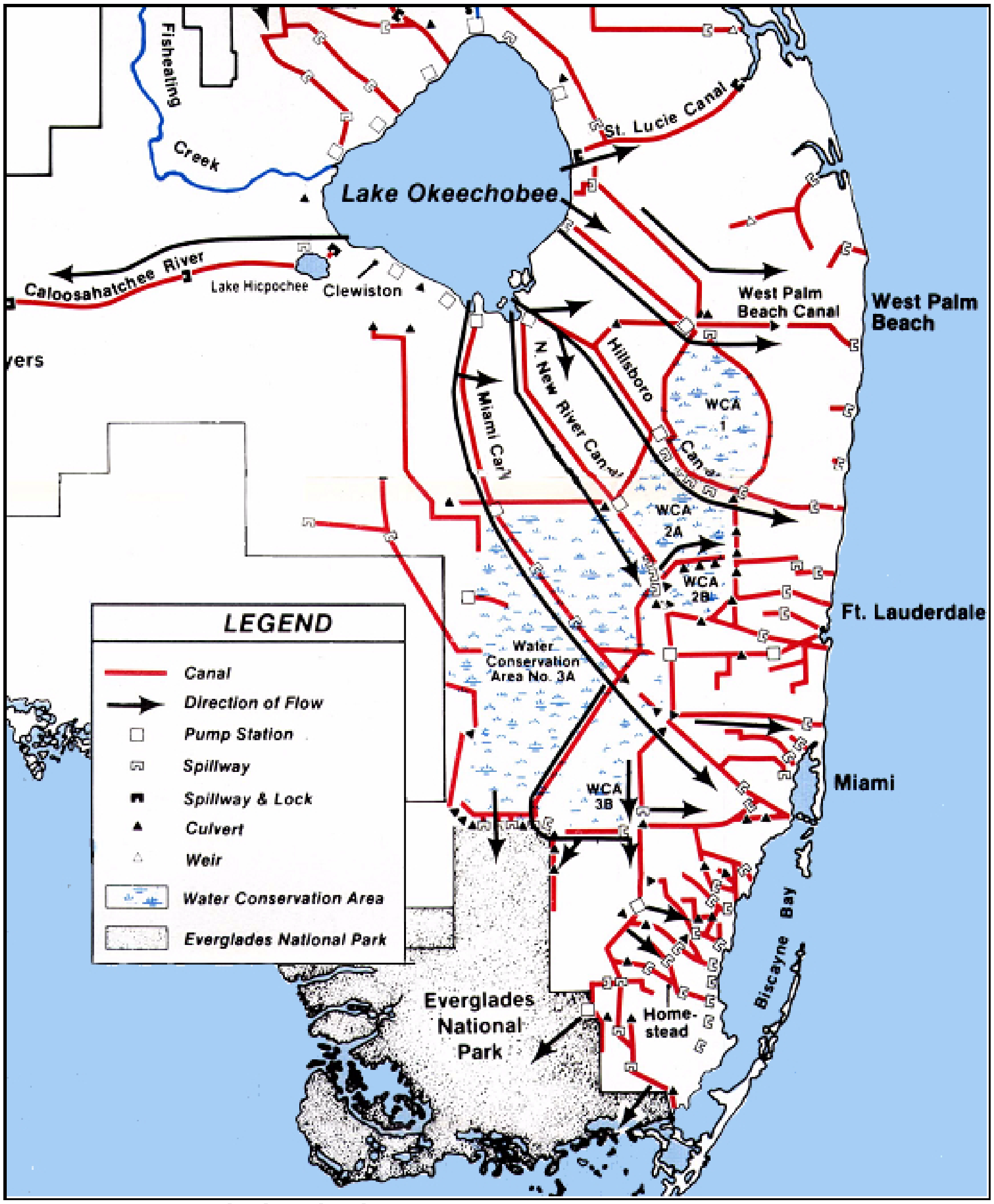


Figure 24. Water Conveyance in the Regional Systems During Dry Period. Arrows Indicate Direction of Pumpage or Flow.

Supply-Side Management

Water supply allocations from Lake Okeechobee during a drought are determined based on the Supply-Side Management Plan. According to this plan, the amount of water available for use during any period is a function of the anticipated rainfall, lake evaporation and water demands for the balance of the dry season in relation to the amount of water currently in storage. Water availability in Lake Okeechobee is calculated on a weekly basis, along with a provision that allows users to borrow from their future supply to supplement existing shortfalls. The borrowing provision places the decision of risk with the user and can significantly affect the distribution of benefits among users because the amount of water borrowed is mathematically subtracted from future allocations. Supply-side management is implemented if it is projected that the lake could fall below 11 ft NGVD at the end of the dry season (**Figure 25**).

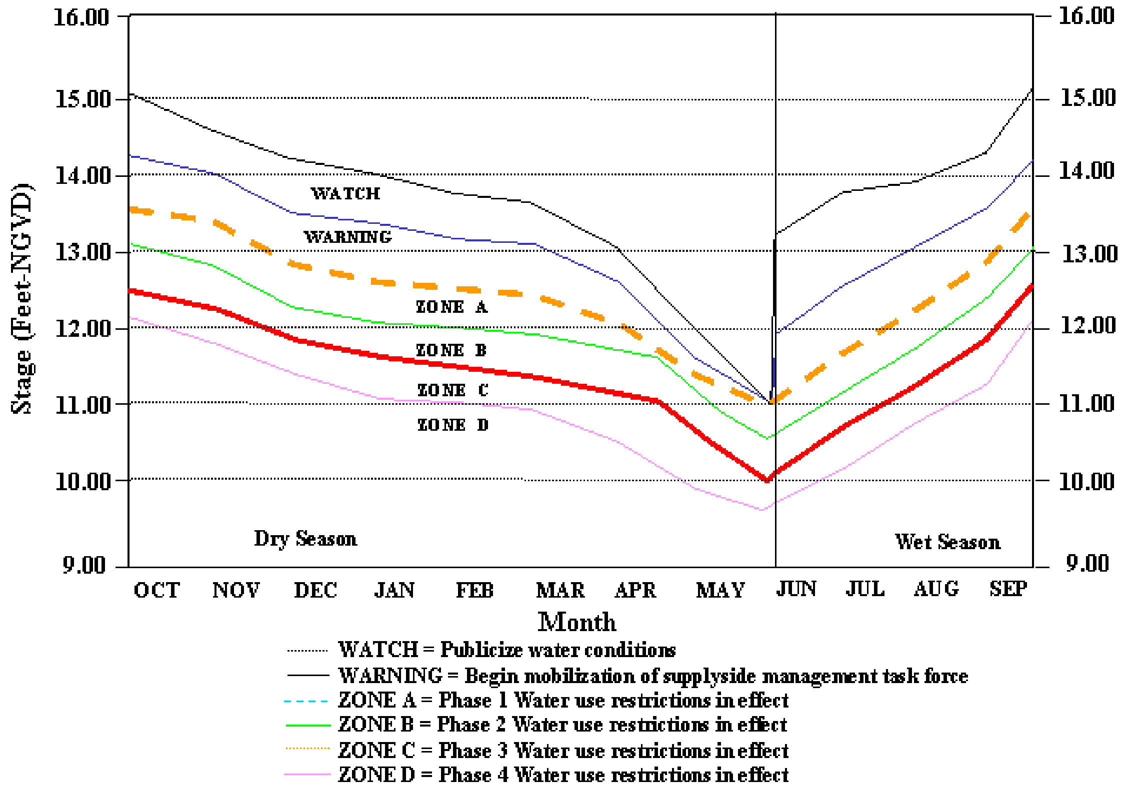


Figure 25. Lake Okeechobee Supply-Side Management Plan.

For Lake Okeechobee, the procedure is based on a calculation of irrigation water demands in four agricultural basins: the North Shore, the Caloosahatchee, the St. Lucie and the EAA. Lower East Coast urban demands were omitted because they are not generally required during a normal rainfall year; however, these demands can be significant during dry periods. Another major omission from this calculation is the environmental demand. As part of the LEC Plan, recommendations for improvements to supply-side management and water shortage management will be made to better address urban and environmental water needs.

Water Shortage Frequencies

The frequency of water shortages is defined based on statistical analysis of data from a particular monitoring station, basin or region. The numbers represent the estimated time period between occurrences of events that have similar magnitude. Drought events can be defined for different time periods (monthly, dry season, wet season, annual and biannual) based on a number of different criteria, including lack of sufficient rainfall, lack of adequate water levels in the aquifer or lack of water available in the regional system.

For example, assume that the average rainfall is 54 inches per year in a particular basin and rainfall of 47 inches occurs that year. Based on statistical analysis of historical data from rainfall monitoring stations within this basin, this degree of deficiency was determined to occur once every ten years. Annual rainfall of 47 inches corresponds to a 1-in-10 year drought condition for that basin based on rainfall. Different water management actions may be required, depending on the location, nature and magnitude of the drought.

Glossary

Aquifer A portion of a geologic formation or formations that yield water in sufficient quantities to be a supply source.

Aquifer Storage and Recovery (ASR) The injection of fresh water into a confined aquifer during times when supply exceeds demand (wet season), and recovering it during times when there is a supply deficit (dry season).

Aquifer System A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

Artesian When groundwater is confined under pressure greater than atmospheric pressure by overlying relatively impermeable strata.

Available Supply The maximum amount of reliable water supply including surface water, groundwater and purchases under secure contracts.

Backpumping The practice of actively pumping water leaving an area back into a surface water body.

Basin (Groundwater) A hydrologic unit containing one large aquifer or several connecting and interconnecting aquifers.

Basin (Surface Water) A tract of land drained by a surface water body or its tributaries.

Bathymetry The measurement of water depth at various places in a body of water.

Best Management Practices (BMPs) Agricultural management activities designed to achieve an important goal, such as reducing farm runoff or optimizing water use.

Biochemical Oxygen Demand (BOD) The amount of dissolved oxygen required to meet the metabolic needs of aerobic microorganisms in water rich in organic matter, such as sewage. Also known as Biological Oxygen Demand.

Biscayne Aquifer A portion of the Surficial Aquifer System, which provides most of the fresh water for public water supply and agriculture within Miami-Dade, Broward and southeastern Palm Beach County. It is highly susceptible to contamination due to its high permeability and proximity to land surface in many locations.

Boulder Zone A highly transmissive, cavernous zone of limestone within the lower Floridan Aquifer.

Brackish Water with a chloride level greater than 250 mg/L and less than 19,000 mg/L.

Central and Southern Florida Project Comprehensive Review Study (Restudy) A five-year study effort that looked at modifying the current Central and Southern Florida Project (C&SF Project) to restore the greater Everglades and south Florida ecosystem, while providing for the other water-related needs of the region. The study concluded with the Comprehensive Plan being presented to the Congress on July 1, 1999. The recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project, are being further refined and will be implemented in the Comprehensive Everglades Restoration Plan (CERP).

Central and Southern Florida Flood Control Project (C&SF Project) A complete system of canals, storage areas and water control structures spanning the area from Lake Okeechobee to both the east and west coasts, and from Orlando south to the Everglades. It was designed and constructed during the 1950s by the United States Army Corps of Engineers (USACE) to provide flood control and improve navigation and recreation.

Clastic Rock or sediment composed of individual grains or fragments from physical breakdown of a larger mass, which have been transported from its place of origin.

Comprehensive Everglades Restoration Plan (CERP) The recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project are being further refined and will be implemented through this plan.

Conservation Rate Structure A water rate structure that is designed to conserve water. Examples of conservation rate structures include but are not limited to, increasing block rates, seasonal rates and quantity-based surcharges.

Consumptive Use Use that reduces an amount of water in the source from which it is withdrawn.

Consumptive Use Permitting (CUP) The issuance of permits by the SFWMD, under authority of Chapter 40E-2, F.A.C., allowing withdrawal of water for consumptive use.

Control Structures A man-made structure designed to regulate the level/flow of water in a canal of water body (e.g., weirs, dams).

Demand The quantity of water needed to be withdrawn to fulfill a requirement.

Demographic Relating to population or socioeconomic conditions.

Desalination A process that treats saline water to remove chlorides and dissolved solids, resulting in the production of fresh water.

District Water Management Plan (DWMP) Regional water resource plan developed by the District under Section 373.036, F. S.

Districtwide Water Supply Assessment (DWSA) Document providing water demand assessments, projections and descriptions of the surface water and groundwater resources within each of the SFWMD's four planning areas.

Domestic Use Use of water for household purposes of drinking, bathing, cooking or sanitation.

Drawdown The vertical distance a water level is lowered resulting from a withdrawal at a given point.

Electrodialysis Dialysis that is conducted with the aid of an electromotive force applied to electrodes adjacent to both sides of the membrane.

Evapotranspiration (ET) Water losses from the surface of water and soils (evaporation) and plants (transpiration).

Everglades Agricultural Area (EAA) The area of histosols (muck) south of Lake Okeechobee, which is used for agricultural production.

Exotic Plant Species A nonnative species that tends to out-compete native species and become quickly established, especially in areas of disturbance or where the normal hydroperiod has been altered.

Flatwoods (Pine) Natural communities that occur on level land and are characterized by a dominant overstory of slash pine. Depending on soil drainage characteristics and position in the landscape, pine flatwoods habitats can exhibit xeric to moderately wet conditions.

Florida Administrative Code (F.A.C.) The Florida Administrative Code is the official compilation of the administrative rules and regulations of state agencies.

Florida Department of Environmental Protection (FDEP) The SFWMD operates under the general supervisory authority of the FDEP, which includes budgetary oversight.

Floridan Aquifer System (FAS) A highly used aquifer system composed of the upper Floridan and lower Floridan Aquifers. It is the principal source of water supply north of Lake Okeechobee and the upper Floridan Aquifer is used for drinking water supply in parts of Martin and St. Lucie counties. From Jupiter to south Miami, water from the Floridan Aquifer System is mineralized (total dissolved solids are greater than 1,000 mg/L) along coastal areas and in southern Florida.

Florida Statutes (F.S.) The Florida Statutes are a permanent collection of state laws organized by subject area into a code made up of titles, chapters, parts and sections. The Florida Statutes are updated annually by laws that create, amend, or repeal statutory material.

Florida Water Plan State-level water resource plan developed by the FDEP under Section 373.036, F.S.

Governing Board Governing Board of the South Florida Water Management District.

Groundwater Water beneath the soil surface, whether or not flowing through known and definite channels.

Harm As defined for consumptive use permitting in Chapter 40E-2, F.A.C., the temporary loss of water resource functions that results from a change in surface or groundwater hydrology and takes a period of one to two years of average rainfall conditions to recover.

Hydropattern The pattern of inundation or saturation of an ecosystem.

Hydroperiod The frequency and duration of inundation or saturation of an ecosystem. In the context of characterizing wetlands, the term hydroperiod describes that length of time during the year that the substrate is either saturated or covered with water.

Indicator Region A grouping of model grid cells within the SFWMM consisting of similar vegetation cover and soil type. By grouping cells, the uncertainty of evaluating results from a single two by two, square mile grid cell that represents a single water management gage is reduced.

Infiltration The movement of water through the soil surface into the soil under the forces of gravity and capillarity.

Intermediate Aquifer System (IAS) This aquifer system consists of five zones of alternating confining and producing units. The producing zones include the Sandstone and mid-Hawthorn Aquifers.

Irrigation The application of water to crops and other plants by artificial means.

Irrigation Audit A procedure in which an irrigation systems application rate and uniformity are measured.

Irrigation Efficiency The average percent of total water pumped or delivered for use that is delivered to the root zone of a plant.

Karst Topography formed over limestone, dolomite or gypsum and characterized by sinkholes, caves and underground drainage.

Lake Okeechobee Largest freshwater lake in Florida. Located in central Florida, the lake measures 730 square miles and is the second largest freshwater lake wholly within the United States.

Leakance Movement of water between aquifers or aquifer systems.

Leak Detection Systematic method to survey the distribution system and pinpoint the exact locations of hidden underground leaks.

Levee An embankment to prevent flooding, or a continuous dike or ridge for confining the irrigation areas of land to be flooded.

Level of Certainty Probability that the demands for reasonable-beneficial uses of water will be fully met for a specified period of time (generally taken to be one year) and for a specified condition of water availability (generally taken to be a drought event of a specified return frequency). For preparing regional water supply plans, the goal associated with identifying the water supply demands of existing and future reasonable beneficial uses is based upon meeting those demands for a drought event with a 1-in-10 year return frequency.

Marsh A frequently or continually inundated non-forested wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Microirrigation The application of water directly to, or very near to the soil surface in drops, small streams or sprays.

Minimum Flow and Level (MFL) The point at which further withdrawals would cause significant harm to the water resources.

Mobile Irrigation Laboratory (MIL) A vehicle furnished with irrigation evaluation equipment that is used to carry out on-site evaluations of irrigation systems and to provide recommendations on improving irrigation efficiency.

Mutagen An agent that raises the frequency of mutation above the spontaneous or background rate; a compound having the ability to produce a change in the DNA of a cell.

National Geodetic Vertical Datum (NGVD) A nationally established reference for elevation data relative to sea level.

Natural Resources Conservation Service (NRCS) A federal agency that provides technical assistance for soil and water conservation, natural resource surveys and community resource protection.

Organics Involving organic or products of organic life; relating to or composed of chemical compounds containing hydrocarbon groups.

Permeability Defines the ability of a substrate to transmit fluid.

Point Source Any discernible, confined and discrete conveyance from which pollutants are or may be discharged, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel or other floating craft. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

Pollutant Load Reduction Goal (PLRG) Targeted reduction in pollutant loading to a water body needed to achieve watershed management goals.

Potable Water Water that is safe for human consumption.

Potentiometric The level to which water will rise when a well is drilled into a confined aquifer.

Public Water Supply (PWS) Utilities that provide potable water for public use.

Reasonable-Beneficial Use Use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner, which is both reasonable and consistent with the public interest.

Reclaimed Water Water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility.

Regional Water Supply Plan (RWSP) Detailed water supply plan developed by the District under Section 373.0361, F.S., providing an evaluation of available water supply and projected demands, at the regional scale. The planning process projects future demand for 20 years and develops strategies to meet identified needs.

Reservoir A man-made or natural water body used for water storage.

Restudy Shortened name for C&SF Restudy.

Retrofit The replacement of existing equipment with equipment of higher efficiency.

Reuse The deliberate application of water that has received at least secondary treatment, in compliance with the Florida Department of Environmental Protection and water management district rules, for a beneficial purpose.

Reverse Osmosis (RO) A membrane process for desalting water using applied pressure to drive the feedwater (source water) through a semipermeable membrane.

Saline Water Water with a chloride concentration greater than 250 mg/L, but less than 19,000 mg/L.

Saline Water or Saltwater Interface The hypothetical surface of chloride concentration between fresh water and saline water, where the chloride concentration is 250 mg/L at each point on the surface.

Saline Water or Saltwater Intrusion This occurs when more dense saline water moves laterally inland from the coast, or moves vertically upward, to replace fresher water in an aquifer.

Seawater Water which has a chloride concentration equal to or greater than 19,000 mg/L.

Seepage Irrigation Irrigation that conveys water through open ditches. Water is either applied to the soil surface (possibly in furrows) and held for a period of time to allow infiltration, or is applied to the soil subsurface by raising the water table to wet the root zone.

Self-Supplied The water used to satisfy a water need, not supplied by a public water supply utility.

Semi-confining Layers Layers with little or no horizontal flow, restricting the vertical flow of water from one aquifer to another. The rate of vertical flow is dependent on the head differential between the aquifers, as well as the vertical permeability of the sediments in the semi-confining layer.

Serious Harm The long-term loss of water resource functions, as addressed in Chapters 40E-21 and 40E-22, F.A.C., resulting from a change in surface or groundwater hydrology.

Significant Harm As defined in Rule 40E-8.021(28), F.A.C., the temporary loss of water resource functions, which result from a change in surface or groundwater hydrology, that takes more than two years to recover, but which is considered less severe than serious harm.

Slough A channel in which water moves sluggishly, or a place of deep muck, mud or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands.

Stage The water surface elevation of a water body.

Standard Project Flood (SPF) A mathematically derived set of hydrologic conditions for a region that defines the water levels that can be expected to occur in a basin during an extreme rainfall event, taking into account all pertinent conditions of location, meteorology, hydrology and topography.

Storm Water Surface water resulting from rainfall runoff that does not percolate into the ground or evaporate.

Stormwater Treatment Area (STA) A system of water quality treatment wetlands that use natural biological processes to reduce levels of nutrients and pollutants from surface water runoff.

Subsidence The loss of soil-bulk caused by the oxidation, decomposition and shrinkage of organic material.

Superfund Site Identified by the U.S. Environmental Protection Agency (USEPA) as an uncontrolled or abandoned hazardous waste site having high health and environmental risk and eligible for federal funding to ensure proper remediation and cleanup.

Supply-side Management The conservation of water in Lake Okeechobee to ensure that water demands are met, while reducing the risk of serious or significant harm to natural systems.

Surface Water Water that flows, falls or collects above the soil or substrate surface.

Surface Water Improvement and Management (SWIM) A plan prepared pursuant to Chapter 373, F. S.

Surficial Aquifer System (SAS) Often the principal source of water for urban uses within certain areas of south Florida, this aquifer is unconfined, consisting of varying amounts of limestone and sediments that extend from the land surface to the top of an intermediate confining unit.

Total Maximum Daily Load (TMDL) The level of loading to a body of water that will protect uses and maintain compliance with water quality standards (defined in the *Clean Water Act*).

Total Trihalomethane (TTHM) A sum of chloroform, bromodichloromethane, dibromochloromethane and bromoform.

Transmissivity A term used to indicate the rate at which water can be transmitted through a unit width of aquifer under a unit hydraulic gradient. It is a function of the permeability and thickness of the aquifer, and is used to judge its production potential.

Turbidity The measure of suspended material in a liquid.

Ultralow Volume Plumbing Fixtures Water-conserving plumbing fixtures that meet the standards at a test pressure of 80 pounds per square inch (psi) listed below.

Toilets - 1.6 gal/flush

Showerheads - 2.5 gal/min.

Faucets - 2.0 gal/min.

Uplands Elevated areas that are characterized by non-saturated soil conditions and support flatwood vegetation.

Wastewater The waterborne discharge from residences, commercial buildings, industrial plants and institutions together with any groundwater, surface runoff or leachate that may be present.

Water Conservation Reducing the demand for water through activities that alter water use practices, improve efficiency in water use, and reduce losses of water, reduce waste of water, alter land management practices and/or alter land uses.

Water Conservation Areas (WCAs) Part of the original Everglades ecosystem that is now diked and hydrologically controlled for flood control and water supply purposes. These are located in the western portions of Miami-Dade, Broward and Palm Beach counties, and preserve a total of 1,337 square miles, or about 50 percent of the original Everglades.

Water Resource Development The formulation and implementation of regional water resource management strategies, including: the collection and evaluation of surface water and groundwater data; structural and nonstructural programs to protect and manage the water resource; the development of regional water resource implementation programs; the construction, operation and maintenance of major public works facilities to provide for flood control, surface and underground water storage and groundwater recharge augmentation; and, related technical assistance to local governments and to government-owned and privately owned water utilities.

Watershed The drainage area from which all surface water drains to a common receiving water body system.

Water Shortage Declaration If there is a possibility that insufficient water will be available within a source class to meet the estimated present and anticipated user demands from that source, or to protect the water resource from serious harm, the governing board may declare a water shortage for the affected source class. (Rule 40E-21.231, F.A.C.) Estimates of the percent reduction in demand required to match available supply is required and identifies which phase of drought restriction is implemented. A gradual progression in severity of restriction is implemented through increasing phases. Once declared, the District is required to notify permitted users by mail of the restrictions and to publish restrictions in area newspapers.

Water Supply Development The planning, design, construction, operation and maintenance of public or private facilities for water collection, production, treatment, transmission or distribution for sale, resale or end use.

Weir A barrier placed in a stream to control the flow and cause it to fall over a crest. Weirs with known hydraulic characteristics are used to measure flow in open channels.

Wetland Drawdown Study Research effort by the South Florida Water Management District to provide a scientific basis for developing wetland protection criteria for water use permitting.

Wetlands Areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Xeriscape™ Landscaping that involves seven principles: proper planning and design; soil analysis and improvement; practical turf areas; appropriate plant selection; efficient irrigation; mulching; and appropriate maintenance.

References Cited

Adams, K.M., 1992. *A Three-Dimensional Finite-Difference Ground Water Flow Model of the Surficial Aquifer in Martin County, Florida*. Technical Publication 92-02, SFWMD, West Palm Beach, FL.

American Water Works Association. 1988. *Water Desalting and Reuse Committee Report: Membrane Desalting Technologies for Municipal Water Supply*. AWWA, Denver, CO. 33 pp.

American Water Works Association. 1990. *Water Quality and Treatment*. Fourth Edition. New York, NY: McGraw-Hill.

American Water Works Association. 2003. *Ultraviolet Light (UV) Disinfection Fact Sheet.* AWWA, Denver, CO. Available from: http://www.awwa.org.

Benson, R. and L. Yuhr. 1993. *Salt-water Intrusion Monitoring: An Overview and Approach to Measurements*. Presentation for Natural Resources Department, Broward County. Miami, FL: Technos, Inc.

Brown, M. P., and Reece, D.E., 1979. *Hydrogeologic Reconnaissance of the Floridan Aquifer System, Upper East Coast Planning Area.* Technical Map Series 79-1, pls. 1-10B, SFWMD, West Palm Beach, FL.

Bush, P.W., and Johnston, R.H., 1988, *Ground Water Hydraulics, Regional Flow, and Ground Water Development of the Floridan Aquifer System in Florida and in Parts of Georgia, South Carolina and Alabama*: U.S. Geological Survey, Professional Paper 1403-C, 80 pp.

Butler, D.E. and Padgett, D.G.J., 1995. *A Three-Dimensional Finite-Difference Ground Water Flow Model of the Surficial Aquifer in St. Lucie County, Florida.* Technical Publication 95-01, SFWMD, West Palm Beach, FL.

Chamberlain, R.H, D.E. Haunert, P.H. Doering, K.M Haunert, J.M. Otero, and A.D. Steinman. 1995. *Preliminary Estimate of Optimum Freshwater Inflow to the Caloosahatchee Estuary, Florida*. Technical Memorandum, Department of Ecosystem Restoration, SFWMD, West Palm Beach, FL.

Cooper, R.M. and R. Santee. 1988. *An Atlas of Martin County Surface Water Management Basins*. Technical Memorandum. Resource Planning Department, SFWMD, West Palm Beach, FL. 48 pp.

Cooper, R.M. and T.W. Ortel. 1988. *An Atlas of St. Lucie County Surface Water Management Basins*. Technical Memorandum. Resource Planning Department, SFWMD, West Palm Beach, FL. 40 pp.

Cooper, C.M. and J. Roy 1991. *An Atlas of Surface Water Management Basins in the Everglades: The Water Conservation Areas and Everglades National Park*. Water Resources Division, Department of Research and Evaluation, SFWMD, West Palm Beach, FL.

Davis, J.H. 1943. *The Natural Features of Southern Florida, Especially the Vegetation of the Everglades.* Bulletin No. 25, Florida Geological Survey, Tallahassee FL.

Federico, A.C., K.G. Dickson, C.R. Kratzer and F.E. Davis. 1981. *Lake Okeechobee Water Quality Studies and Eutrophication Assessment*. Technical Publication #81-2, SFWMD, West Palm Beach, FL.

Florida Department of Environmental Protection. 2003a. *Florida Department of Environmental Protection Reuse Inventory*. Tallahassee, FL. vari. pag.

Florida Department of Environmental Protection. 2003b. *Evaluation of Water Conservation in Florida's Water Supply Planning Process*. Tallahassee, FL. vari. pag.

Florida Department of Environmental Protection and South Florida Water Management District. 2000. *Loxahatchee River Wild and Scenic River Management Plan Update*. FDEP and SFWMD. West Palm Beach, FL..126 pp.

Gleason, P. J. (Ed.). 1984. *Environments of South Florida: Present and Past II*. Miami Geological Society, Coral Gables, FL. 551 pp.

Gosselink, J., M.J. Duever, L. Gunderson, and F.E. Mazzotti. 1994. *Report of the Technical Panel on Interim Criteria to Limit the Drawdown of Aquifers for Wetland Protection*. West Palm Beach, FL. 22 pp.

Hall, C.A. 1991. *Lake Okeechobee Supply-Side Management Plan*. Operations and Maintenance Department, SFWMD, West Palm Beach, FL.

Hamann, C.L., J.B. McEwen, and A.G. Myers. 1990. *Guide to Selection of Water Treatment Processes*. In: F.W. Pontius (Ed.), Water Quality and Treatment. Fourth Edition. New York, NY: McGraw-Hill. 157-187 pp.

Haunert, D., K. Konyha. 2001. *Establishing St. Lucie Estuary Watershed Inflow Targets to Enhance Mesohaline Biota Report On Mesohaline Conditions*, Indian River Lagoon – South Feasibility Study, Appendix E. Watershed Management Department, SFWMD, West Palm Beach, FL

Hittle, C.D., 1999. *Delineation of Saltwater Intrusion in the Surficial Aquifer System in Eastern Palm Beach, Martin, and St. Lucie Counties, Florida, 1997-98*. U.S. Geological Survey Water-Resources Investigations Report 99-4214.

Hoffbuhr, J. 1998. *American Water Works Association Public Affairs Advisory: Announcement of Stage 1 of the Disinfectant/Disinfection By-product Rule (D/DBP)*. AWWA, Denver, CO. Available from: http://www.awwa.org.

Johnson Engineering, Inc., Camp Dresser & McKee Inc., Hole, Montes & Associates, W. Dexter Bender & Associates, Darby & Way, Inc., and Greiner Engineering Sciences, Inc. 1990-91. *Lee County Interim Surface Water Management Plan*. Volumes I, II A&B, and III. Prepared for the Board of County Commissioners of Lee County. vari. pag.

Johnson Engineering, Inc. 1990-92. *Six Mile Cypress Watershed Plan*. Volumes I- III. Prepared for the Board of County Commissioners of Lee County. Johnson Engineering Inc., Fort Myers, FL. vari. pag.

Kahl, M. P. 1964. *Food Ecology of the Wood Stork (Mycteria americana)*. Ecol. Monogr., 34:97-117.

Knapp, M.S., W.S. Burns, T.S. Sharp, and G. Shih. 1984. *Preliminary Water Resource Assessment of the Mid and Lower Hawthorn Aquifers in Western Lee County, Florida*. Technical Publication 84-10. Groundwater Division, SFWMD, West Palm Beach, FL. 106 pp.

Lukasiewicz, J. 1992. *A Three-dimensional Finite Difference Groundwater Flow Model of the Floridan Aquifer System in Martin, St. Lucie and Eastern Okeechobee Counties in Florida*. Technical Publication 92-03. Department of Research and Evaluation, SFWMD, West Palm Beach, FL. 292 pp.

Lukasiewicz, J. and M. P. Switanek, 1995. *Ground Water Quality in the Surficial and Floridan Aquifer Systems Underlying the Upper East Coast Planning Area.* Technical Publication WRE-329 95-04, SFWMD, West Palm Beach, FL.

Maloney, F.E., R.C. Ausness and J.S. Morris. 1972. *A Model Water Code*. Publication No. 8. Water Resource Center Gainesville, University of Florida, Gainesville, FL. 349 pp.

Meyer, F.W., 1989. *Hydrogeology, Ground-Water Movement, and Subsurface Storage in the Floridan Aquifer System in Southern Florida.* U.S. Geological Survey Professional Paper 1403-G.

Miller, J.A. 1986. *Hydrogeologic Framework of the Floridan Aquifer System in Florida, and Parts of Georgia, South Carolina, and Alabama*. U.S. Geologic Survey, Professional Paper 1403-B, 91 pp.

Montgomery, James M. Consulting Engineers. 1985. *Water Treatment Principles and Design*. New York, NY: John Wiley and Sons.

Ogden, J.C. and S.M. Davis. 1994. *Everglades: The Ecosystem and Its Restoration*. St. Lucie Press, Delray Beach, FL.

O'Reilly A.M., R.M. Spechler and B.E. McGurk. 2002. *Hydrogeology and Water-Quality Characteristics of the Lower Floridan Aquifer in East-Central Florida.* U.S. Geological Survey Water Resources Investigations Report 02-4193.

Parker, G., G.E. Gorginsen, and S.K. Love. 1955. *Water Resources of Southeastern Florida*. USGS Water-Supply Paper 1255. Department of the Interior, U.S. Geological Survey, Washington, D.C. 965 pp.

Pyne, D. 1995. *Ground Water Recharge and Wells: A Guide to Aquifer Storage Recovery.* Boca Raton, FL: CRC.

Reese, R.S. 2000. *Hydrogeology and the Distribution of Salinity in the Floridan Aquifer System, Southwestern Florida*. U.S. Geological Survey, Water Resources Investigations Report 98-4253.

Reese, R.S. and K. J. Cunningham, 2000. *Hydrogeology of the Gray Limestone Aquifer in Southern Florida.* U.S. Geological Survey Water-Resources Investigations Report 99-4213.

Reese, R.S. and S.J. Memberg, 2000. *Hydrogeology and the Distribution of Salinity in the Floridan Aquifer System, Palm Beach County, Florida.* U.S. Geological Survey Water-Resources Investigations Report 99-4061.

Reese, R.S., 2002. *Hydrogeology and Sources of Salinity in the Floridan Aquifer System, Martin and St. Lucie Counties, Florida*. U.S. Geological Survey Water-Resources Investigations Report DRAFT.

Sepulveda, N. 2002. *Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida* U.S. Geological Survey Water Resources Investigations Report 02-4009.

Smith, Keith R. and Karin Adams. 1988. *Ground Water Resource Assessment of Hendry County, Florida*. Technical Publication 88-12, Parts I and II. Hydrogeology Division, SFWMD, West Palm Beach, FL. 109 pp.

Southeastern Geologic Ad Hoc Committee on Florida Hydrostratigraphy Unit Definition. 1986. *Hydrogeologic Units of Florida: Florida Department of Natural Resources*. Bureau of Geology, Special Publication 28, 9 pp.

South Florida Water Management District. 1991. *Water Supply Policy Document*. Planning Department, SFWMD, West Palm Beach, FL. 82 pp.

South Florida Water Management District. 1992. *Water Supply Needs and Sources*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1993. *Canal Conveyance Capacity of C-23*. Prepared for the SFWMD by Greiner, Inc. SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1995a. *Biscayne Bay Surface Water Improvement and Management Plan*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1995b. *District Water Management Plan, Volume I*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1995c. *District Water Management Plan, Volume II*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1997. *Surface Water Improvement and Management Plan for Lake Okeechobee*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 1998. *Districtwide Water Supply Assessment*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 2000. *District Water Management Plan*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 2002a. *District Water Management Plan Update*. Water Supply Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 2002b. *Indian River Lagoon Surface Water Improvement and Management Plan Update*. SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 2002c. *Lake Okeechobee Protection Program Annual Report*. Northern District Restoration Department, SFWMD, West Palm Beach, FL.

South Florida Water Management District. 2002d. *Lake Okeechobee Supply-Side Management Draft – Work In Progress*. Water Supply Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District. 2003a. *Basis of Review for Water Use Permit Applications within the South Florida Water Management District*. Environmental Resource Regulation Department, SFWMD, West Palm Beach, FL.

South Florida Water Management District. 2003b. *Surface Water and Improvement Management Plan for Lake Okeechobee*. Northern District Restoration Department, SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District and St. Johns River Water Management District. 2002. *Surface Water and Improvement Management Plan for the Indian River Lagoon*. SFWMD, West Palm Beach, FL. vari. pag.

South Florida Water Management District, United States Army Corps of Engineers and Florida Department of Environmental Protection. 2003. *Adaptive Protocols for Lake Okeechobee Operations.* SFWMD, West Palm Beach, FL.

South Florida Water Management District and St. Johns River Water Management District. 1994. *Surface Water and Improvement Management Plan for the Indian River Lagoon*. Planning Department, SFWMD, West Palm Beach, FL. vari. pag.

Southwest Florida Water Management District. 2002a. *Average Reclaimed Water Flows for Residential Customers in Paseo, Pinellas, and Hillsborough Counties.* SWFWMD. Brooksville, FL.

Southwest Florida Water Management District. 2002b. *Tampa Bay Area Regional Reclaimed Water Initiative.* SWFWMD. Brooksville, FL.

St. Johns River Water Management District. 1994. *Water Supply Needs and Sources Assessment*. Technical Publication SJ94-7. SJRWMD, Palatka, FL. vari. pag.

St. Johns River Water Management District. 1997. *Water Supply Needs and Sources Assessment: Alternative Water Supply Strategies Investigation, Water Supply and Wastewater Systems Component Cost Information.* Technical Publication SJ97-SP3. Law Engineering and Environmental Services, Inc. for SJRWMD, Palatka, FL.

Stangland, H. 1999. Ardaman and Associates, Inc. *Letter of H. Stangland Regarding Lower Florida Aquifer*. Orlando, FL.

Tampa Bay Water. 2003. *Tampa Bay Seawater Desalination Plant Providing Drinking Water to the Region*. News Release. Clearwater, FL. Available from: http://www.tampabaywater.org.

Tibbals, C.H. 1990. *Hydrology of the Floridan Aquifer System in East-Central Florida*. U.S. Geological Survey Professional Paper 1403-E.

Trimble, P. and J. Marban. 1988. *Preliminary Evaluations of the Lake Okeechobee Regulation Schedule*. Technical Publication 88-5. Water Resources Division, SFWMD, West Palm Beach, FL.

United States Army Corps of Engineers and South Florida Water Management District. 1998. *Specific Superfund (National Priority List: NPL) and RCRA Hazardous Waste Sites in South Florida - Appendices H and K*. The Central and Southern Florida Flood Control Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. USACE, Jacksonville District, Jacksonville, FL, and SFWMD, West Palm Beach, FL.

United States Army Corps of Engineers and South Florida Water Management District. 1999. *Central and Southern Florida Flood Control Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement*. USACE, Jacksonville District, Jacksonville, FL, and SFWMD, West Palm Beach, FL.

United States Army Corps of Engineers. 1999. *Lake Okeechobee Regulation Schedule Study – Final Environmental Impact Statement. Planning Document*. USACE, Jacksonville District, Jacksonville, FL.

United States Army Corps of Engineers. 2000. *Water Control Plan for Lake Okeechobee and the Everglades Agricultural Area*. USACE, Jacksonville District, Jacksonville, FL.

United States Environmental Protection Agency – Indian River Lagoon National Estuary Program. 1996. *Indian River Lagoon Comprehensive Conservation and Management Plan.* Sponsored by the St. Johns River Water Management District and South Florida Water Management District, Melbourne, FL.

United States Environmental Protection Agency. 1998a. *SDWA Section 1401(4) Public Water System Definition as Amended by 1996 SDWA Amendments*. Federal Register Vol. 63, No. 150 part VI 7.

United States Environmental Protection Agency. 1998b. *National Primary Drinking Water Regulation: Interim Enhanced Surface Water Treatment Rule*. Federal Register, Vol. 63, No. 241, 40 CFR Parts 9, 141, and 142.

United States Environmental Protection Agency. 2000. *Coastlines – Information About Estuaries and Near Coastal Waters.* USEPA, Office of Wetlands, Oceans, & Watersheds, Washington, D.C.

University of Florida. 1982. *Wetland Loss in South Florida and the Implementation of Section 404 of the Clean Water Act*. A report to the Office of Technology Assessment, Oceans and Environment Program, U.S. Congress. Center for Government Responsibility, University of Florida College of Law, Gainesville, FL. 124 pp.

University of Florida. 1993. *Florida Statistical Abstract*. Bureau of Economic and Business Research, UF, Gainesville, FL: University Presses of Florida.

Water Science and Technology Board, 1996. *Use of Reclaimed Water and Sludge in Food Crop Production*. Commission on Geosciences, Environment, and Resources. National Research Council, Washington, D.C., National Academy Press.

Wedderburn, L., M. Knapp, D. Waltz and W. Burns. 1982. *Hydrogeologic Reconnaissance of Lee County, Florida*. Technical Publication 82-1. SFWMD, West Palm Beach, FL. 192 pp.